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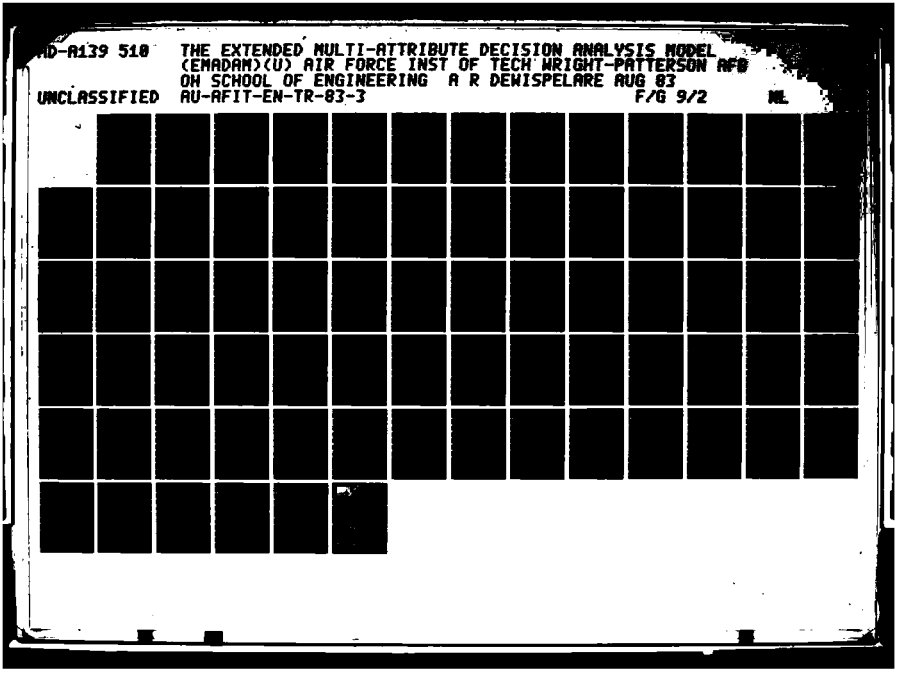

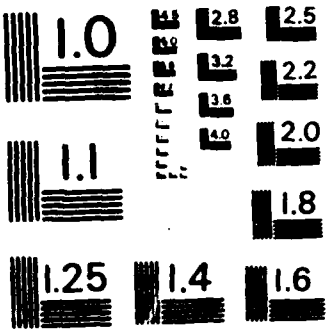

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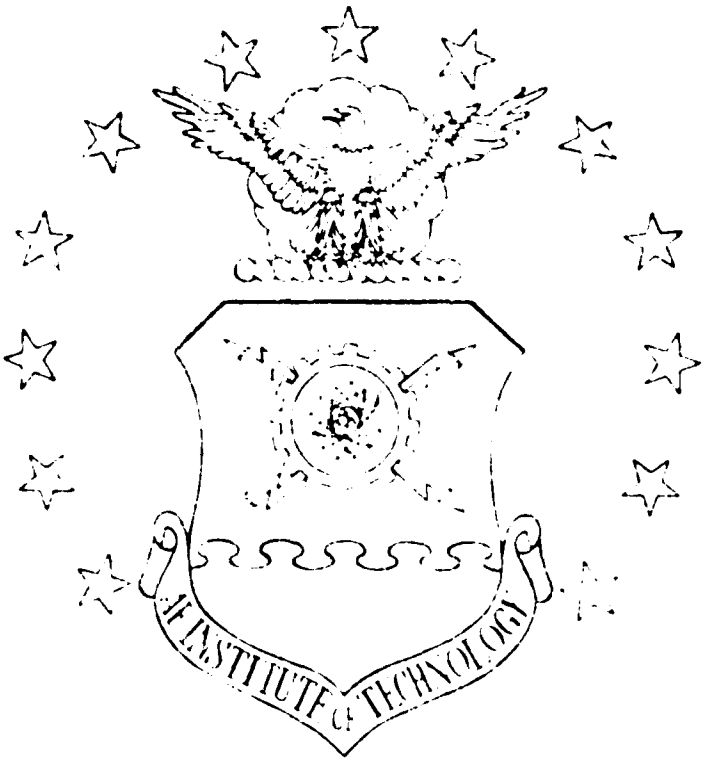

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THE EXTENDED MULTI-ATTRIBUTE DECISION ANALYSIS MODEL (EMADAM)

TECHNICAL REPORT

AFIT-EN-TR-83-3 AARON R. DEWISPELARE

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TECHNICAL REPORT AU-AFIT-EN-TR-83-3
AUGUST 1983

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SCHOOL OF ENGINEERING
AIR FORCE INSTITUTE OF TECHNOLOGY
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

THE EXTENDED MULTI-ATTRIBUTE DECISION ANALYSIS MODEL (EMADAM)

Capt. Aaron R. DeWispelare*

Abstract

This research is an on-going effort to produce an interactive, computer-based aid suitable for use in decision situations and long-term planning. The current research involves the development of extensions to the applicability of a decision aid embodied in the computer program MADAM: Multi-Attribute Decision Analysis Model. The theoretical underpinnings of MADAM involve portions of multi-attribute utility theory. This interactive program is designed to aid the decision-maker in all phases of decision analysis from problem formulation to sensitivity analysis. The program is a tool designed to be used by a decision-maker in order to facilitate making rational and consistent trade-offs and subdecisions throughout the entire decision-making process. The stages of the decision analysis covered by the program include formation of an objectives hierarchy, elicitation of an appropriate set of attributes, examining the relationship between the attributes, establishing criterion weights, evaluating candidate solutions, and performing several types of sensitivity analysis.

The significant changes in the model involve the stages of examining the relationship between the attributes and of incorporating probabilistic data and utility concepts. In the previous version of MADAM, the program guides the decision-maker in determining whether or not the condition of mutual preferential independence is met. This determination is important because the previous version of the program is designed to handle the case of deterministic attributes (measurable value analysis) where an additive value function is the appropriate overall value function. The exentsions allow MADAM to be utilized for the case of probabilistic attributes (utility analysis). The extended program aids the decision-maker in conducting lottery trade-offs so that independence conditions necessary to use an additive utility function can be ascertained. The utility analysis parallels the former value analysis in structure. MADAM maintains all previous capabilities for sensitivity analysis as well as the new utility analysis capabilities.

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1. Introduction

Decision situations are becoming increasingly complex due to the desire by decision makers to have as much information as possible with which to resolve the situation. This desire for increased quantity and quality information has encouraged analysts to attempt to quantify previously qualitatively addressed concepts and to utilize increasingly robust models to more realistically describe the world. Because of complications in gaining access to the decision maker (DM), in presenting data, and in interpreting the data, a very thorough analysis may never be used or inefficiently used in the resolution of a decision situation (7,6,11). It is hypothesized that it would be beneficial to develop tools to help the DM prioritize salient attributes and quantify preferences in an easily usable format. One technological boom which can help achieve this objective is the availability of inexpensive, computationally capable, and conveniently small computers (15). These computers can manage and display data pertinent to a decision situation, and they can be used in real-time sessions with an individual DM or a group of decision makers.

One tool which has been developed is the software package (MADAM, 16, 17). This computer program is similar to other interactive decision aids which attempt to automate value (deterministic utility) structure elicitation from the DM (4,10,15). The program MADAM approaches a decision situation from a multiple attribute value theory paradigm. It attempts to guide an analyst and/or DM through the steps of structuring the problem in terms of objectives and attributes, quantifying the DM's preferences, evaluating candidate solutions, and performing sensitivity analysis with respect to the preference structure and alternative realizations of candidate solutions. The current capability of this interactive program is conducting a value elicitation (deterministic in nature) with a DM concerning the attributes and candidate solutions for a decision situation, and allowing for several types of sensitivity analyses.

Among applications which are appropriate for utilizing a program like MADAM are evaluation of competing alternatives, ranking of projects, and the testing of the robustness of a solution. As an example, the government could use this program as a decision aid in prioritizing research projects within budgetary constraints. Annually, there are a certain amount of funds left to the discretion of government laboratory managers for dispersement into appropriate research efforts. The universal problem that these DM's face is that there are apparently more deserving projects than resources to adequately fund them. Government DM's could use the decision aid MADAM to evaluate these projects and resolve their dilemma. A major deficiency which is noted in using programs like MADAM is the inability to account (explicitly) for the probability of achieving particular attribute levels among the various projects. The ability to incorporate risk when using decision support software would expand its usefulness because of the need to differentiate among alternatives which are non-deterministic in nature.

This paper describes and motivates the implementation of the modifications to the computer program MADAM. These modifications expand the capability of the computer automated decision aid by allowing for the incorporation of risk and subsequent utility aspects of candidate solutions. The incorporation of the DM's attitude toward risk in a Multiple Attribute Utility Theory (MAUT) model is discussed in Section 2. The actual computer program modifications developed and then implemented in code (FORTRAN) on a mainframe computer are described in Section 3 (See also Appendix A). The modified decision aid program allows interactive operation and contains graphics capability for rapid feedback to the analyst and DM. Section 4 (and Appendix B) delineates a hypothetical application of this decision tool which concerns the prioritization of various types of government research projects by a DM. The primary aim of this effort is to expand the capabilities of MADAM to explicitly address and incorporate elements of risk. The second aim of this effort is to illustrate how this new expanded decision aid may be applied to the government research project prioritization problem.

2. Multiple Attribute Utility Theory

MAUT is widely used in decision situations which involve event outcome uncertainty (2,7,11,12,14). These events have associated with them outcome probabilities formed from either empirical data, or subjective data obtained from expert opinion. The objective of MAUT is to find a scalar scoring function (SSF) which will map each alternative in the decision situation onto the real line, and in the process form a complete ordering (ranking) of all alternatives. For the case which involves uncertainty, the objective is to find the alternative which maximizes the expected utility of the DM. For the discrete cases, this is given by

$$\underset{a_i}{\text{Maximize}}\ e(u) = E \sum_j p_j(a_i)u(z_{ij}(a_i)) \qquad (1)$$

over each alternative a_i where E is the expectation operator, p_j is the probability of the jth event outcome, z_{ij}. The SSF, u, is a utility function which incorporates the DM's attitudes toward risk. This function can be formed by combining the salient attributes of the decision situation into a single attribute and then transforming it to a utility function incorporating risk (3), or by use of decomposition techniques which form constitutent utility functions for the salient attributes and then aggregating these into a scalar function. Many authors including Keeney and Raiffa (11) describe assessment procedures for this latter method which enable one to discern the mathematical form of u and to identify scaling parameters based on the relationships among the attributes. This latter method is used to build the models described in Section 3. The alternative policies, events, outcomes and associated probabilities in a MAUT formulation can usually be displayed in a decision tree format such as the simplified single state tree shown in Figure 1. A general algorithm of the MAUT process is shown in the DELTA chart of Figure 2.

2.1 Computerized MAUT

Computers have the potential to significantly enhance the assessment of multiple attribute utility and value functions. This has been demonstrated by recent research

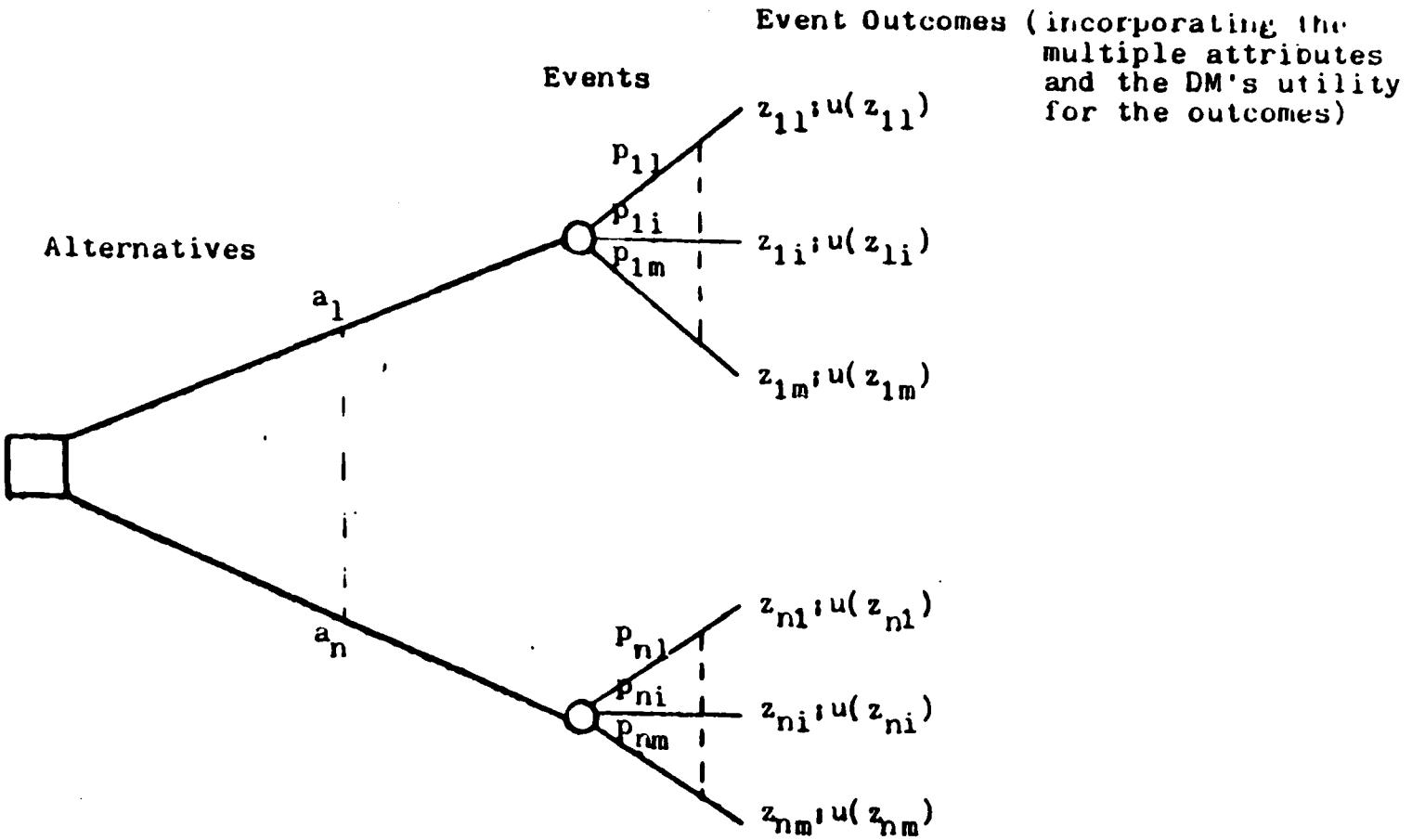

Figure 1. Single Stage Decision Tree Representation Of The Decision Situation

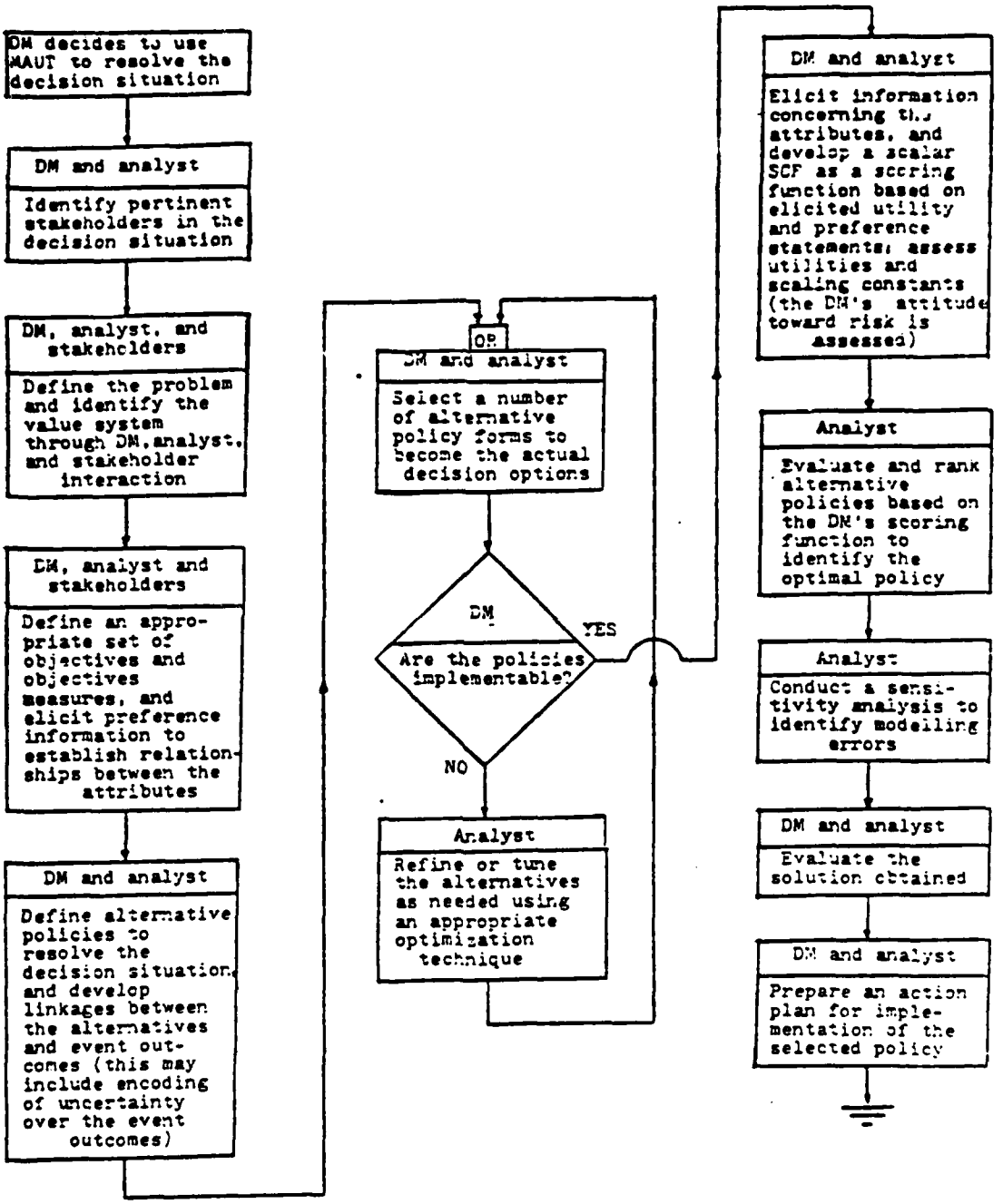

Figure 2. DELTA Chart For MAUT Process With Uncertain Outcomes

in the case of a single decision maker (10) and also in the case of group decision-making (15). The development of the previous computerized assessment packages have fallen short in many areas. These deficiencies include: 1) the failure to incorporate the DM's attitude toward risk on an individual attribute basis; 2) the lack of a systematic way to incorporate descriptions of the candidate alternatives in terms of stochastically based raw attribute data; 3) the lack of immediate feedback to the DM of the implications of his preferences; 4) the lack of an efficient procedure to update DM preferences and conduct sensitivity analysis. The computer program MADAM originally did a satisfactory job of assessing value functions and evaluating alternatives with deterministic outcomes. It did not ameliorate the first two previously mentioned deficiencies concentrated around the lack of incorporation of the elements of uncertainty in a decision situation. However the structure of MADAM made it attractive to modify the program by adding several subroutines which allowed all of the aforementioned deficiencies to be appropriately addressed and resolved in the context of risk and utility. Section 3 describes the specific models and accompanying procedures which are implemented in structured subroutines on the digital computer.

3. Utility/Risk Incorporation Into MADAM

3.1 Previous Capabilities of MADAM

MADAM was designed for a complex decision making environment which exhibited characteristics of Type I and Type III problems of Figure 3. The modifications in this effort which incorporated utility concepts into MADAM are intended to allow for solutions to decision problems of Type II and IV. Originally, a DM/analyst was able to use MADAM to conduct interactively a problem formulation phase, the formation of an appropriate value function, and a sensitivity analysis phase. The DELTA chart of Figure 4 shows the program flow for the problem formulation phase of MADAM. In the problem formulation phase, the DM is guided in the construction of an objectives hierarchy which is designed to define issues of concern; limit the

Outcome Under:	Single Attribute	Multiple Attribute
Certainty	Type I	Type III
Uncertainty	Type II	Type IV

Figure 3. MAUT Formulation Typology

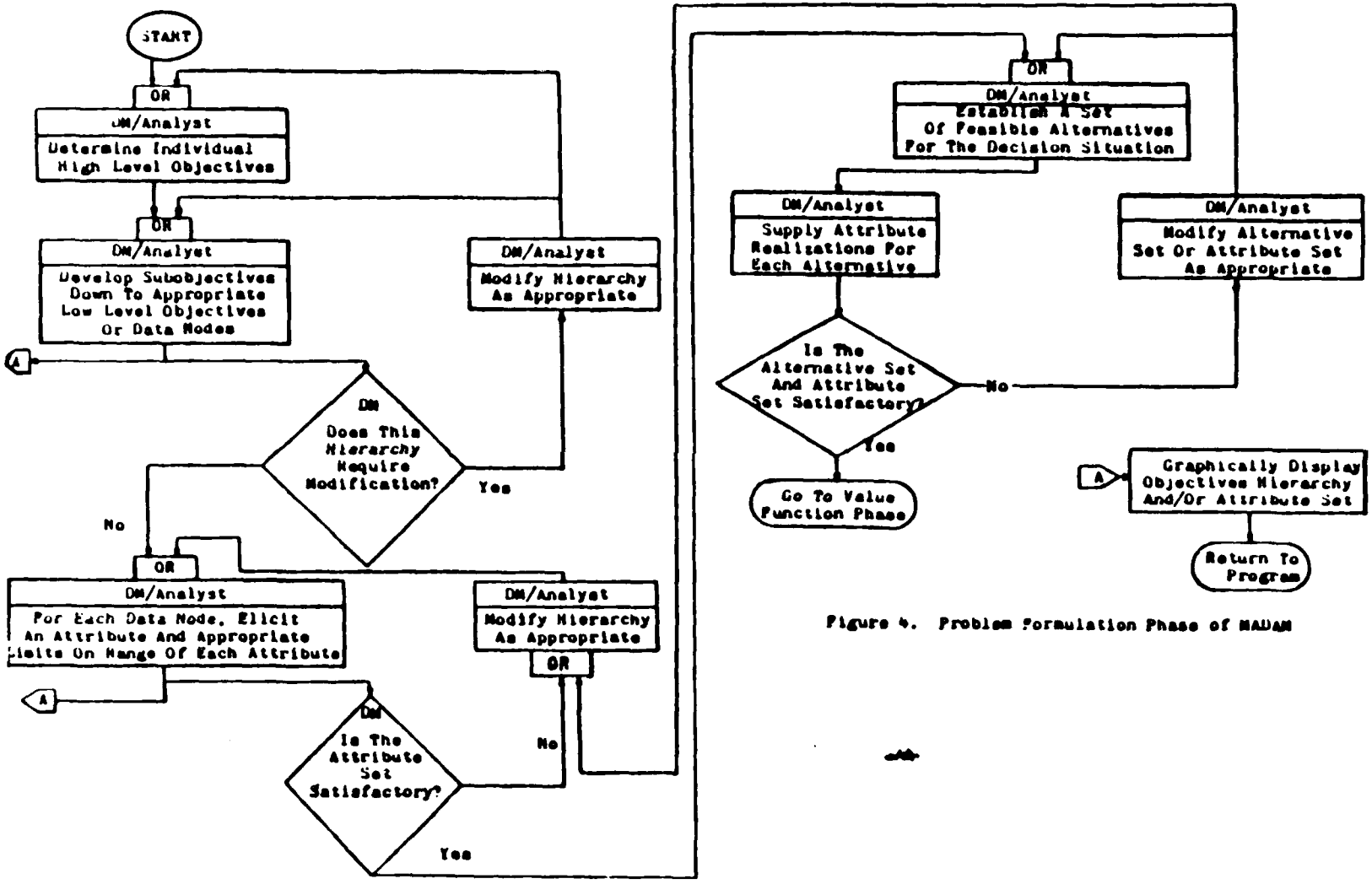

Figure 4. Problem Formulation Phase of MAUAM

problem to a tractable size, and identify operational variables or attributes. Additionally, the problem formulation phase establishes an appropriate range of realization levels for each attribute, and characterizes a feasible set of candidate solutions or alternatives in terms of these attributes. There is graphics capability for the appropriate timely feedback of the objectives hierarchy and attribute set to the DM.

The next phase of MADAM explores relationships among the attributes in attempting to establish mutual preferential independence (MPI), and then establishes constituent scoring or value functions for the individual attributes. MADAM uses the weakened sufficiency conditions (12) of pairwise preferential independence (PPI) to explore the existence of MPI. MPI among attributes is both necessary and sufficient for justifying use of the additive form of value function.

$$V_{(x)} = \sum_{i=1}^{n} W_i \cdot v_i (x_i) \qquad (2)$$

where V(x) is the scalar value function, $v_i(x_i)$ is a constituent value function of an individual attribute x_i, and W_i is a scaling constant reflecting the relative criterion weight of attribute x_i compared to the other attributes. Currently MADAM only has the capability of utilizing an additive form of V(x), but caveats are issued automatically if MPI cannot be established warning the DM/analyst of possible error in scoring and ranking the alternatives. The individual value functions are next established using the midvalue spliting technique (11). Once the individual value functions are established, graphical display to the DM of these functions is used to verify their form. Next the scaling constants or criterion weights are elicited using the ratio technique (5,13). Now all parts of the SSF, V(x), are present for evaluation and ranking of each candidate alternative. Figure 5 shows a DELTA chart of the value function establishment pahse.

Sensitivity analysis is performed in the next and last phase of MADAM. Sensitivity to criterion weight changes for upper level nodes and attributes (data nodes) for all alternatives or any alternative individually, and to attribute levels at a particular node for each alternative explored in this phase.

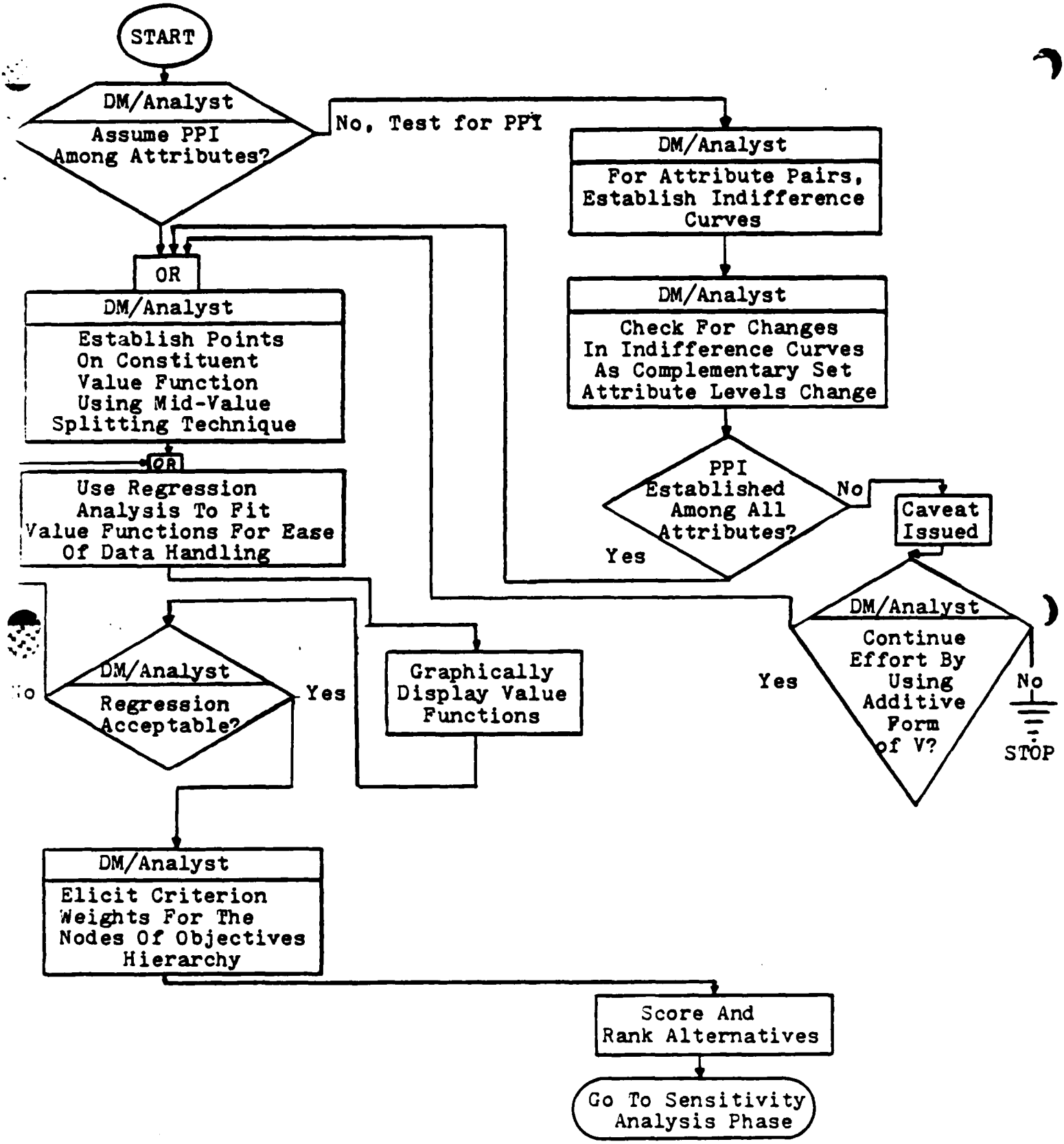

Figure 5. Value Function Phase of MADAM

There is a graphical presentation of the resulting alternative's scores due to the variation of parameters.

In all three phases, only deterministic attribute levels for the alternatives are permissible as input. Also no attempt is made to incorporate the DM's attitude toward the risk involved with each alternative. In the resulting sections, the modifications to MADAM are described which ameliorate these weaknesses.

3.2 Modifications/Current Capabilities of Extended MADAM: EMADAM

The incorporation of stochastic data for alternatives under evaluation and the DM's attitude toward this risk in a utility function was accomplished in three steps: (1) model and implement a protocol for exploring relationships among attributes in terms of utility concepts, 2) model the incorporation of risk into the DM's value function and establishing a protocol for assessing utility functions accompanied by graphical display of these utility functions, 3) model the combination of individual utility functions into a global utility function and then provide a description and subsequent evaluation of candidate alternatives in terms of the risk containing utility development and provide for the inclusion of probabilistic attribute data.

Attribute Relationships

In order to establish a mathematical basis for using a specific utility function with which to score and subsequently rank alternatives, relationships among the attributes must be examined with respect to both the DM's preferences over the attributes and attitude toward risk. A manual approach for checking for Mutual Utility Independence (MUI) among attributes is described by Keeney and Raiffa (11). This approach using PPI and utility independence (UI) for checking for MUI was developed into an algorithm and implemented in a new Subroutine called UPI (Appendix A-3). The flow in UPI is shown in Figure 6.

MUI is both a necessary and sufficient condition for using the multiplicative form of utility function and it is also a necessary condition for using the additive form of utility function as shown in Equation 3 below (11):

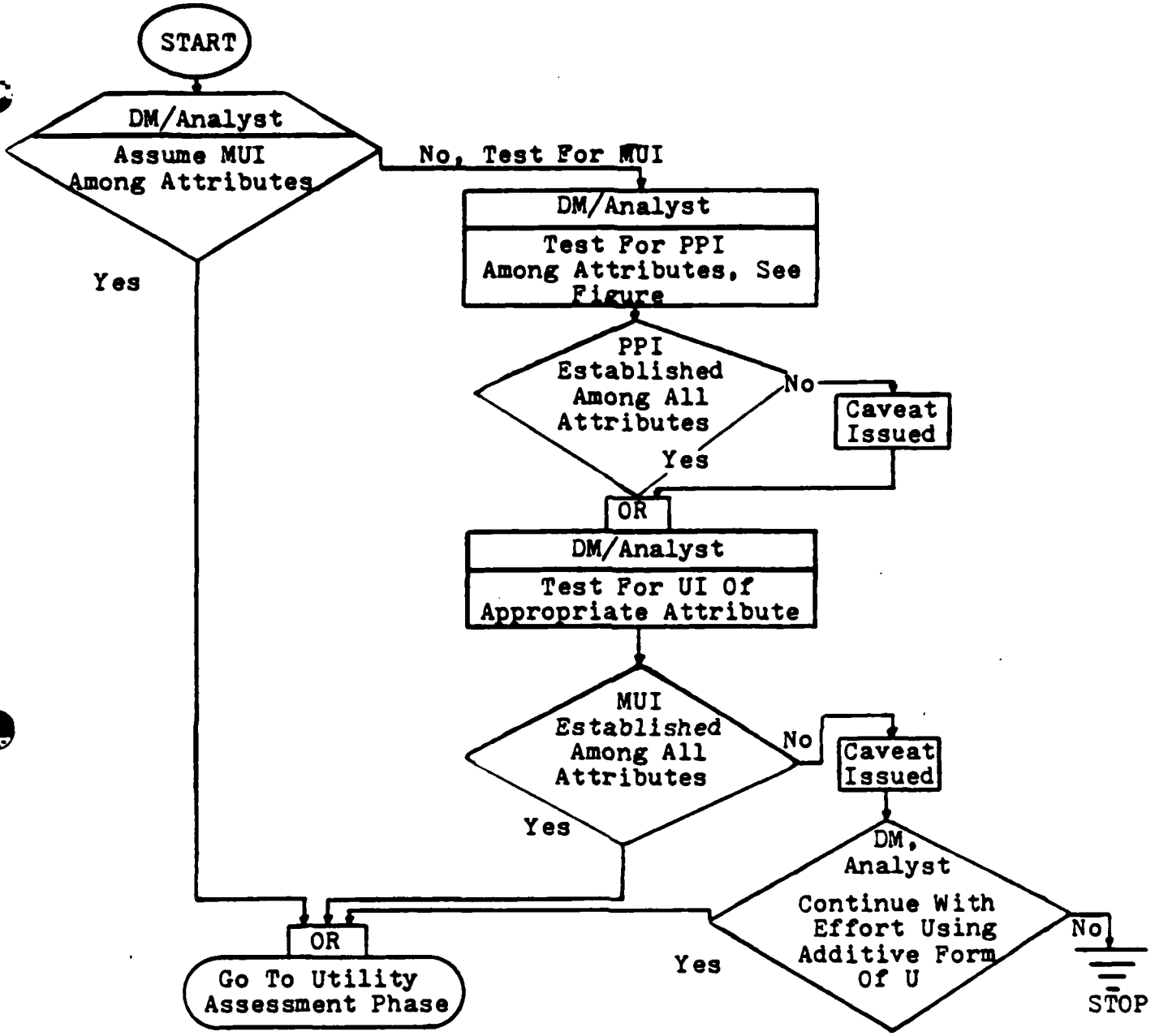

Figure 6. Flow of Subroutine UPI

$$U = \sum_{i=1}^{n} k_i \; u_i(x_i) \qquad (3)$$

where $u_i(x_i)$ represents a constituent utility function, u_i, which is a function of a single attribute, x_i; and k_i represents the criterion weight or scaling constant corresponding to $u_i(x_i)$, and U is the combined utility function for all attributes. The additive form of U is used in this effort since it is the form that applications have shown to be very often justified (11). Sufficient conditions for using the additive form of U are the establishment of Fishburn Marginality but these conditions can become intractable for any practical application where the number of attributes is greater than two (7,11). Caveats are issued if MUI cannot be established and the DM/analyst is given the choice of stopping the analysis or continuing with the knowledge that some error is possible.

Utility Function Assessment

Because MUI is either established or assumed in subroutine UPI, individual utility functions can be established as functions of single attributes. The most common approach for incorporating the DM's attitude toward risk and preference simultaneously is through a simple lottery. Figure 7 shows the construction of a simple lottery where the DM is asked to trade a chance at two outcomes in terms of a single attribute for a minimum amount of the same attribute for certain. This amount is called the certainty equivalent of the lottery (22). The utility of this certainty equivalent can be seen to be equal to the expected utility of the lottery which is calculated using Equation 1. A series of questions in the form of lotteries can define a utility curve for a single attribute. In the assessment process, the probabilities are held constant, and the outcomes are varied. A series of questions in the form of lotteries can define a utility curve for a single attribute. In the assessment process, the probabilities are held constant, and the outcomes are varied. While there may be some drawbacks in using the lottery technique (4), it is by far the most often used technique for assessing a DM's utility (2,11,12). This lottery technique was developed into an algorithm and implemented in Subroutine UTIL

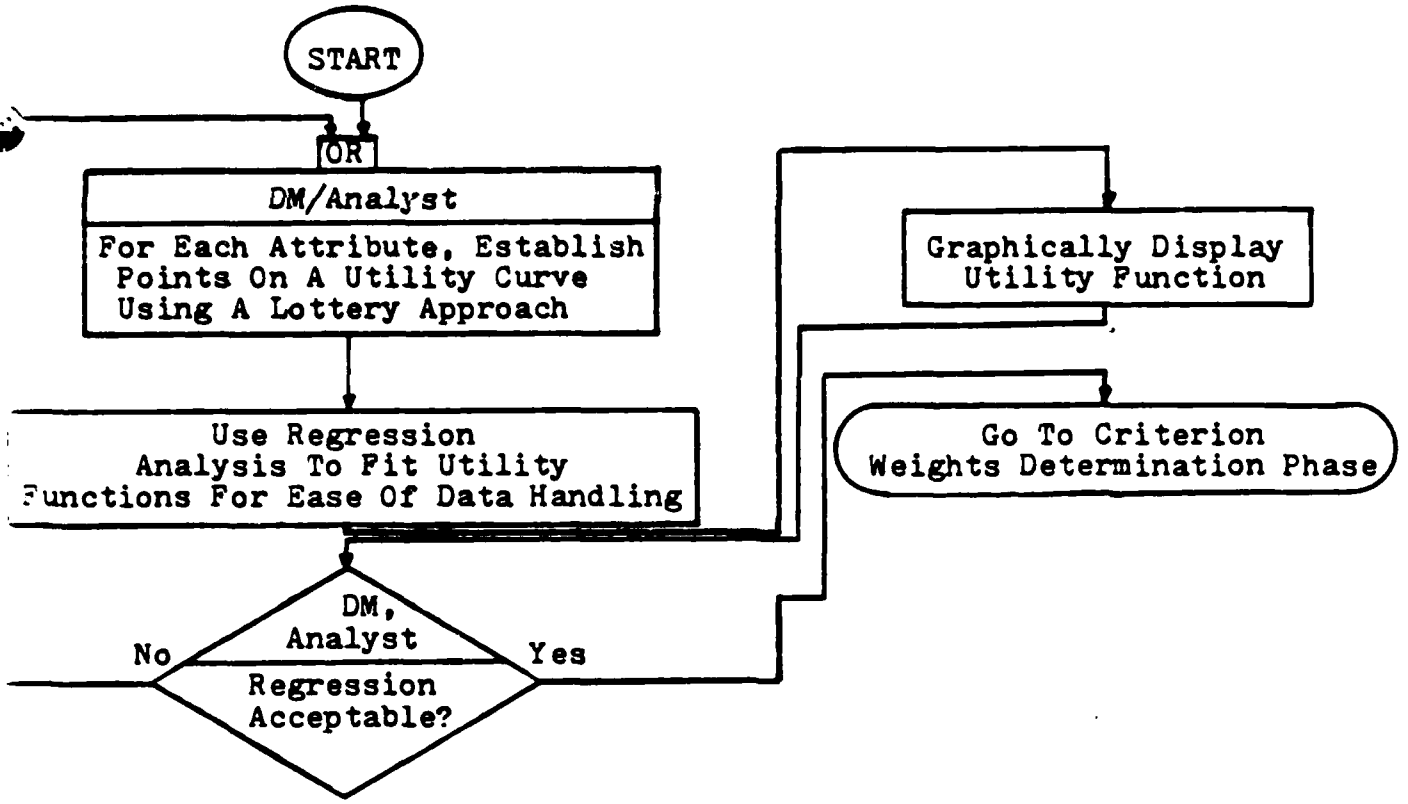

Figure 8. Flow of Subroutine UTIL and Adjoining Modules

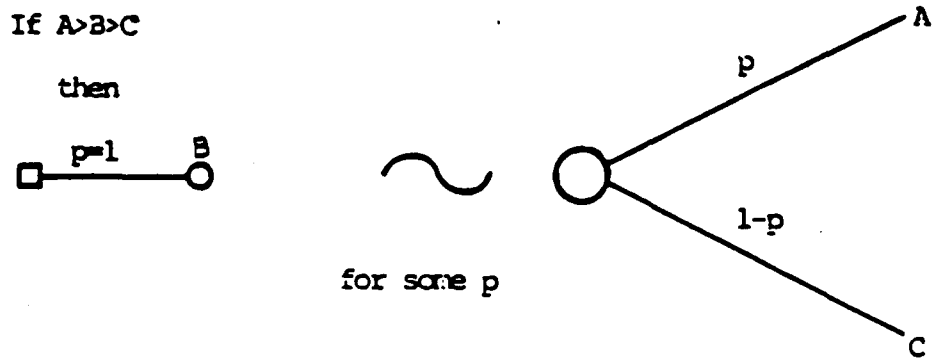

Figure 7. Simple Lottery

(Appendix A2).

The points of the constituent utility curves just determined are curve fit using a least squares criterion for five forms (exponential, quadratic, linear, logarithm, and square root). The closest fit of the regression attempts is parameterized for ease of data handling for all utility curves. The regression results and error are displayed to DM/analyst. The individual utility functions are graphically presented for the DM/analyst. This visual feedback will corroborate the risk averseness characteristic of each utility curve for each attribute as a consistency check. Subroutines PICTUR and RDATT were modified to accomplish the last two major steps. Figure 8 shows the flow of the utility function assessment.

Probabilistic Data Inclusion/Expected Utility Calculation

The strength of the utility theory approach to decision theory is the ability to take into account the realistic risk associated with levels of the attributes (outcomes occurring in the future) for each alternative. In order to allow for ease of interfacing with the digital computer, the Subroutine RDV (Appendix A-4), asks the analyst to input discretized or spike probability distribution data corresponding to levels of the attributes. A maximum of ten discrete probabilities are allowed for each attribute per alternative. Checks are included to insure that these discrete probabilities are collectively exhaustive. The resulting probability distributions are displayed graphically through Subroutine DRWPRB (Appendix A-6).

The expected utility for each attribute for each alternative is now calculated in Function CONVLT (Appendix A-5) by forming the linear sum shown in Equation 1. Constituent utility values corresponding to the discrete attribute levels just entered are calculated from the previously determined utility curves. These utility values are multiplied by the corresponding probability of occurrence for each attribute. The resulting expecting utilities for each attribute are combined with the previously described scaling constants to produce the linear sum of Equation 3. This results in a combined utility score for a simple alternative. The flow of the data entry and utility calculation phases are shown in Figure 9.

This process is repeated for each alternative. The set of alternatives are ranked and the respective combined utility scores displayed.

The example presented in Section 4 and Appendix B demonstrates the use of the newly enhanced decision aid MADAM for a problem involving probabilistic data and utility concepts.

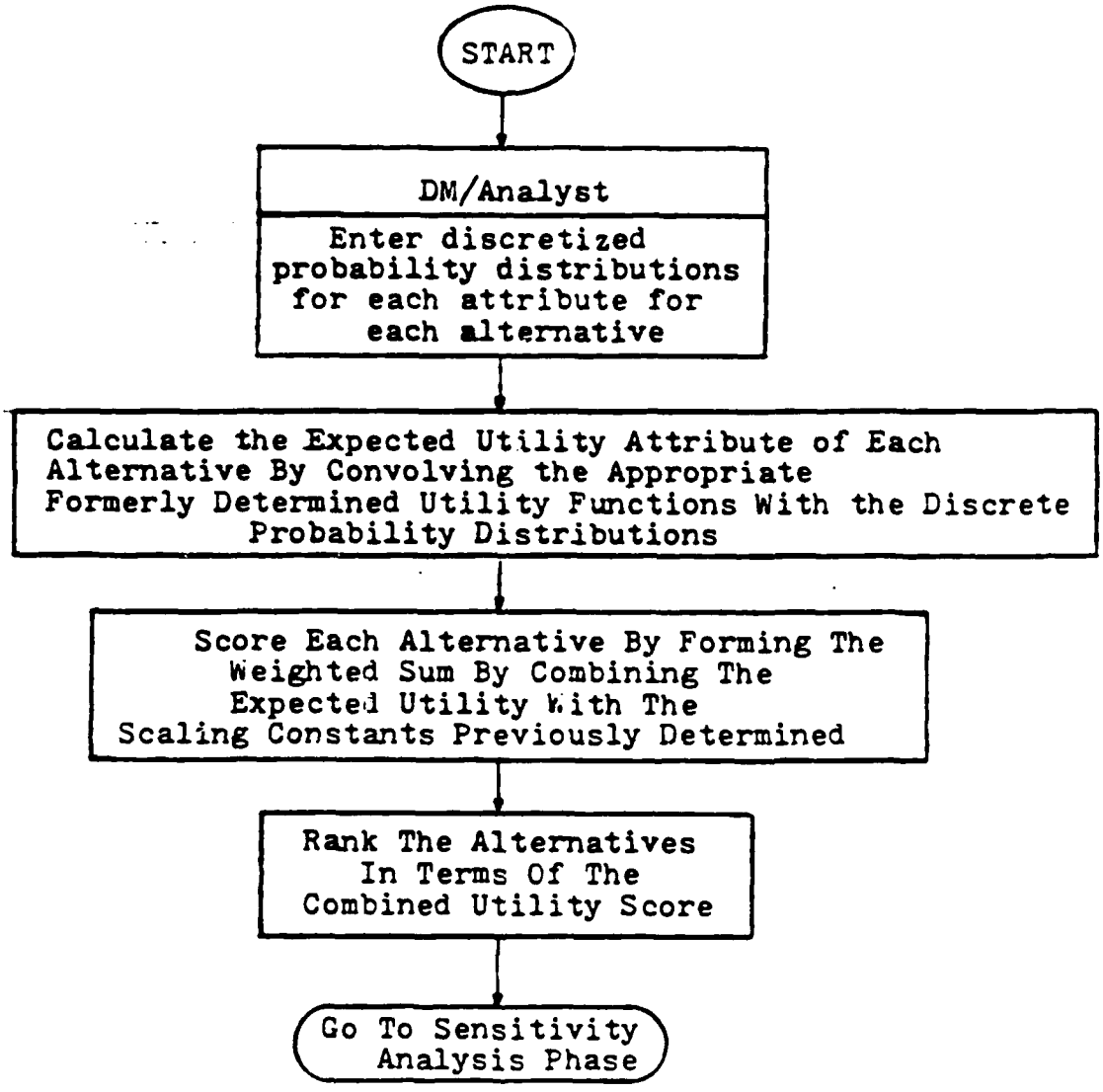

Figure 9. Data Entry/Utility Calculation

4. Prioritizing Research Projects - An Application of EMADAM

4.1 Problem Definition

The Department of Defense (DOD) philosophy on funding initial research and development (R and D) programs (also called "new starts") is to commence efforts in many areas, but only fund the advanced development and eventual procurement of the few - efforts that are the most successful, potentially fruitful, or vitally needed (18,19,20,21). Many government laboratories are apportioned a certain amount of funds to start new R and D projects. Unfortunately there is always insufficient funding to cover all the attractive R and D projects. The problems faced annually by the government research executives are how to rapidly and appropriately prioritize the new R and D efforts. A tool like EMADAM allows the DM and analyst or advisor to work through each phase of the prioritization in an informed and timely manner. This allows for not only a ranking of the projects, but also a more thorough understanding of the process by the parties involved.

To serve as an example of a possible use of EMADAM, a hypothetical application concerning R and D project prioritization is now presented. Appendix B gives an interactive listing of this application of the research project prioritization.

4.2 Attributes

An objectives hierarchy was established for this decision situation (Appendices B and D). The measures of attainment of the lowest level objectives are the attributes for this problem. Four attributes were identified as salient in this decision situation. They are (1) technology base, (2) sponsorship potential, (3) cost, and (4) time to project fruition.

The "technology base" attribute addresses the issue of being able to successfully produce a solution for identified needs as opposed to just expanding the technological base in an area. The end objective of each R and D project is evaluated as to the existing technological base as well as estimated difficulty in achieving the end objective. A ten point scale is used to rate each project

(Appendix C) from the extremes of no technology base and extreme difficulty in achieving research objective to simply a new use of existing well developed technology with little difficulty in achieving end objective. Each project is rated based on an extensive literature search of existing technological bases and expert opinion with respect to difficulty in meeting the research objective within five years. In all cases where expert opinion is used to refine attribute levels, a Delpi exercise is used to achieve concensus (13). There is some uncertainty associated with the estimates of the technology base obtained from expert opinion.

The "sponsorship potential" attribute is aimed at ascertaining the number of potential major organizations which will commit funds toward advanced development and pre-production testing. This attribute is used as the primary indicator of the importance of the deficiency or need addressed by a project. Zero through five major organizations is the range of this attribute. Surveys with the potentially interested major organizations are the primary source of data for this attribute for each project. Because some organizations withhold their commitment of funds until some future point in time, there is some uncertainty as to the exact number of sponsoring organizations.

The attribute of cost seems to be the most straight forward attribute but modifications of the yearly costs must be made to establish a common time basis for the research projects. All research budgets are made on a five year planning cycle as dictated by Congress. Because projects are generally funded for all five years once they are started, this period is used as the absolute maximum time allowed for each project to reach the identified research objective. Therefore, each project is budgeted so that the research objective can be achieved in five years. The highest cost project is used as the basis or standard and all other projects are allotted the same annual amount. This step resolves the arbitrary nature of funding and puts all projects on the same effective-budget schedule. The fact that many projects would be accelerate. and produce

lts faster than usual at the basis funding level allows project differentiation in the next attribute to be discussed, which is "time to project fruition." This equalizing of the proposed annual budgets for the projects allows the attribute "cost" to be dropped from analysis so as not to double count its effect. This reduces the number of attributes, and makes the decision situation more tractable in quantitative terms.

The "time to fruition" attribute indicates the actual time (less than or equal to five years) for the R and D project to produce significant results (i.e. achieve the research objective). Because many projects will take less than five years to produce significant results at the equalized effective basis funding level discussed earlier, the combination of this attribute and cost will differentiate among the alternatives. Expert opinion and past research efforts are used to produce the estimates of time to fruition for each project. As with the other attributes, risk is involved in this estimate and therefore a distribution is appropriate for describing the attribute level achieved.

4.3 Alternatives

Five generic R and D projects were ranked in this effort. While these projects were hypothetical, they are very similar in characteristics to actual projects. These projects S, T, X, Y, and Z are described in terms of attribute data in Appendix B. Project S has the characteristics of an expected general project with low to average technology base (TB), a reasonable number of sponsors and an average time to successful results. Project T would be called an average development oriented project with a high TB, a few sponsors, and an average expected time to successful development. Project X is the high risk alternative with a low TB, only one sponsor, and a long expected time to fruition. Project Y has the characteristics of a typical research oriented project with a low to average TB, small number of sponsors and a long lead time to successful results. The final alternative, Project Z, is often called a "sure bet" because it has characteristics that almost always assure success in an average amount of time such as a high TB and many sponsors. The specific

attribute values and accompanying probability distributions are shown in Appendix B.

4.4 Results

A government DM familiar with the R and D funds allocation problem was used in this effort to add realism to this example. The objectives hierarchy, attributes, criterion weights (scaling constants), relationships among the attributes, and individual utility functions were all established by the DM in realistic sessions utilizing EMADAM. Appendix B contains an abbreviated but representative listing of the output for this example.

The DM established the objectives hierarchy (Appendix D) which led to the attributes discussed earlier and listed in Appendix B. The DM was able to establish MUI among the attributes which are necessary conditions justifying use of individual utility functions of individual attributes, and the additive form of SSF (Appendix B). The individual utility functions were elicited from the DM (Appendix B), and as expected all indicate an aversion toward risk with respect to all attributes. The utility functions for "time to fruition" and "number of sponsors" displayed the most risk aversion. The criterion weights established by the DM indicate the "number of sponsors" willing to support development (an indication of need, $W_2 = 50$) is almost twice as important as either "time to fruition" ($W_3 = 30$) and TB ($W_1 = 20$) in prioritizing alternative projects (Appendix B). Of course these weights (scaling constants) may only be valid for the ranges of the attributes considered (11).

The calculated expected utilities for the five projects (Appendix B) are as follows: U (Project S) = 64.20, U (Project T) = 64.68, U (Project X) = 27.15, U (Project Y) = 53.74, U (Project Z) = 65.01. On a 100 point normalized scale, some significant differences are evident. Project Z clearly dominates Projects X and Y, but outdistances Projects S and T by only 1%. The usefulness of a quantitative decision aid such as EMADAM is not only in the absolute ranking of the alternatives, but also in the relative differences between alternative project scores. While not a specific objective of this effort, extensive

sensitivity analysis is available with EMADAM as an aid to the DM, and for this example clearly needed to differentiate projects S, T, and Z.

4.5 Computer Utilization Summary

A listing of the routines developed in this effort (ASKU, UTIL, UPI, DRWPBR, CONVLT, and RDV) is provided in Appendix A. These routines are written in FORTRAN V and all graphics capability is compatible with any common alpha-numeric terminal. In addition to the routines coded, many other subroutines in MADAM were modified to allow compatibility of both deterministic and probabilistic data. The subroutines modified were ATT, ASET, ATTSET, PICTUR, and RDATT. The enhanced version of MADAM (i.e. EMADAM) is now in excess of 5,6000 lines of code. EMADAM is segmented in overlays which at no time take more than 56,6000 bytes of memory. This reasonable memory requirement due to overlaying allows for interactive execution of the program. The CPU execution time is nominal for a reasonable size problem. This example problem took less than six seconds total. This example was performed on a CYBER 175 (CDC) system.

The interactive terminal time totaled approximately three hours for this sample. This time was accomplished with the DM in two sessions. The DM expressed satisfaction with the usability and commented on the ease of understanding the prompts provided by the enhanced MADAM program. The length of time required by the DM/analyst does not seem excessive when one considers the number of steps accomplished in the decision resolution paradigm.

5. Summary, Conclusions, and Recommendations

5.1 Summary

In this effort, several modifications to the decision analysis software tool MADAM (16,17) were accomplished. These modifications enhance this decision making aid by incorporating utility concepts and probabilistic data into the analysis process. The DM/analyst can still accomplish the setting of objectives and determination of attributes (Figure 4), and now has the choice and capability

of using an automated tool for exploring relationships among attributes, assess the DM's value or utility functions, and include attribute data for either the probabilistic or deterministic data case (Figures 5, 6, 8, and 9). Several computer codes were developed to implement the modifications accomplished here. These modifications are summarized in the following tasks:

1. model and code a protocol for examining utility and preference relationships among attributes (Subroutine UPI, Appendix A-3);
2. model and code a protocol for the incorporation of risk into the DM's value function and assess his/her utility functions along with graphical display of these curves (Subroutines ASKU and UTIL, Appendices A-1 and A-2);
3. model and code the inclusion of probabilistic attribute data for the alternatives along with graphical presentation of this data, the combination of individual utility functions into a global utility function employing an expected utility calcualtion, and the subsequent evaluation of the utility for each alternative (Subroutines RDV and DRWPRB, and Function CONVLT, Appendices A-4, A-6, and A-5).

5.2 Conclusions

Conclusions to be drawn from this effort:

- The enhanced version of MADAM (EMADAM) can effectively incorporate probabilistic data for the attributes of alternative systems under evaluation, and utility concepts (additive form of utility function) into a decision analysis.
- This type of decision aiding software tool is appropriate to project evaluations and selection problems such as the allocation of government research and development funds as demonstrated by the example in Section 4 and Appendix B.
- The usability of EMADAM appears acceptable as demonstrated on a moderately sized problem (Section 4, Appendix B). A DM, with or without an analyst can execute a decision analysis with EMADAM due to the interactive set of prompts presented by the software.
- The enhanced version of EMADAM is efficient in terms of computer memory required (less than 57K bytes due to over-laying), and in terms of CPU execution time (less than six seconds) for a moderately sized problem (Section 4, Appendix B).

The convenience of interactive operation is somewhat offset by the required terminal time for the DM/analyst (approximately three hours for the example problem delineated in Section 4, Appendix B).

5.3 Recommendations

Two recommendations are offered in response to this effort First, expand EMADAM to accommodate other forms of global utility functions besides the additive form. The multiplicative form (11) would be a tractible function which incorporates non-linearites in a decision situation. Second, develop a more sophisticated procedure to assess the scaling constants (criterion weights). Such a procedure should allow for more consistency checks without inducing obfuscation (5,11).

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Appendix A

Computer Code Enhancements To MADAM

** Appendix A-1 **

```
      SUBROUTINE ASKU(I,X1,X2,XMID)                                     025450
                                                                        025460
                                                                        025470
                                                                        025480
C*****************************************************************      025490
C*                                                               *      025500
C*                                                               *      025510
C*  THIS ROUTINE ASKS THE QUESTIONS WHICH ELICIT THE             *      025520
C*  DATA POINTS FROM WHICH THE ESTIMATED INDIVIDUAL              *      025530
C*  UTILITY FUNCTION MAY BE ESTABLISHED.                                025540
C*                                                               *      025550
C*                                                               *      025560
C*  CALLED BY:  UTIL                                             *      025570
C*                                                               *      025580
C*  VARIABLES                                                    *      025590
C*        USED:  X1,X2,XMAX,XMIN                                 *      025600
C*                                                               *      025610
C*        MODIFIED:  XMID                                        *      025620
C*                                                               *      025630
C*                                                               *      025640
C*****************************************************************      025650
                                                                        025660
                                                                        025670
      DATA                                                              025680
      CHARACTER ATT1*11                                                 025690
                                                                        025700
                                                                        025710
                                                                        025720
                                                                        025730
                                                                        025740
                                                                        025750
1     PRINT*,' '                                                        025760
      PRINT*,'NOW WHAT  LEVEL OF ATTRIBUTE ',ATT1(I)                    025770
      PRINT*,'WITH CERTAINTY WOULD YOU TRADE FOR A LOTTERY'             025780
      PRINT*,'WITH A 50-50 CHANCE OF RECEIVING EITHER'                  025790
      PRINT*,X2,' UNITS OF ',X1,' UNITS OF ATTRIBUTE ',ATT1(I)          025800
      PRINT*,'     ?'                                                   025810
      READ(*,'(F10.0)')XMID                                             025820
      XMIN=AMIN1(X1,X2)                                                 025830
      XMAX=AMAX1(X1,X2)                                                 025840
      IF((XMID.LT.XMIN).OR.(XMID.GT.XMAX))THEN                          025850
      PRINT*,XMID,' IS OUTSIDE THE RANGE OF ',X1,' TO ',X2              025860
      GO TO 1                                                           025870
      ENDIF                                                             025880
      RETURN                                                            025890
      END                                                               025900
```

```
      SUBROUTINE UTIL                                                   027090
                                                                        027100
                                                                        027110
                                                                        027120
*****************************************************************     027130
*                                                               *     027140
*                                                               *     027150
$     THIS ROUTINE GENERATES THE DATA POINTS FROM WHICH THE     *     027160
$     INDIVIDUAL UTILITY FUNCTIONS ARE ESTIMATED, AND CALLS           027170
$     ROUTINE REGRS TO DO THE ESTIMATION.                       *     027180
*                                                               *     027190
*                                                               *     027200
$     CALLED BY:  LPI,RDATT                                     *     027210
*                                                               *     027220
*     VARIABLES                                                 *     027230
*           USED:  NATT,XMID                                    *     027240
*                                                               *     027250
*           MODIFIED:  CH,I,VAL,X                               *     027260
*                                                               *     027270
*                                                               *     027280
*****************************************************************     027290
                                                                        027300
                                                                        027310
      COMMON/ATTR/NATT                                                  027320
      COMMON/VAL/VAL(5)                                                 027330
      SAVE                                                              027340
      CHARACTER CH,ATT1*10                                              027350
      PRINT*,' '                                                        027360
      PRINT*,' '                                                        027370
      PRINT*,' THE UTILITY FUNCTIONS FOR EACH ATTRIBUTE'                027380
      PRINT*,' WILL NOW BE DETERMINED '                                 027390
      PRINT*,' '                                                        027400
      PRINT*,' '                                                        027410
      DO 10 I=1,NATT                                                    027420
1     CALL ASKU(I,ATT(I,2),ATT(I,3),XMID)                               027430
      VAL(1)=ATT(I,2)                                                   027440
      VAL(5)=ATT(I,3)                                                   027450
      VAL(3)=XMID                                                       027460
      X=XMID                                                            027470
      CALL ASKU(I,ATT(I,2),X,XMID)                                      027480
      VAL(2)=XMID                                                       027490
      CALL ASKU(I,ATT(I,3),VAL(3),XMID)                                 027500
      VAL(4)=XMID                                                       027510
      CALL REGRS(I)                                                     027520
      PRINT*,' '                                                       027530
      PRINT*,'THE ABOVE YIELDS A UTILITY FUNCTION FOR ',ATT1(I)         027540
      PRINT*,'WITH PARAMETERS:'                                         027550
      PRINT*,'B1=',PARAM(I,1),'     B2=',PARAM(I,2)                     027560
      PRINT*,'SUM OF SQUARED ERROR=',PARAM(I,3)                         027570
      IF(PARAM(I,4).EQ.0)THEN                                           027580
      PRINT*,'(LINEAR FORM)'                                            027590
      PRINT*,'UTILITY=B1*W + B2*(ATTRIBUTE LEVEL)'                      027600
      ELSEIF(PARAM(I,4).EQ.-1.)THEN                                     027610
      PRINT*,'(SQUARE-ROOT FORM)'                                       027620
      PRINT*,'UTILITY=B1*W + B2*(ATTRIBUTE LEVEL)**0.5'                 027630
```

```
      ELSEIF(PARAM(I,4).EQ.1.0)THEN                                     027640
      PRINT*,'(SQUARED FORM)'                                           027650
      PRINT*,'UTILITY=B0+B1*(ATTRIBUTE LEVEL)**2.0'                     027660
      ELSEIF(PARAM(I,4).EQ.-2.0)THEN                                    027670
      PRINT*,'(LOGARITHMIC FORM)'                                       027680
      PRINT*,'UTILITY=B0+B1*LN(ATTRIBUTE LEVEL)'                        027690
      ELSEIF(PARAM(I,4).EQ.2.0)THEN                                     027700
      PRINT*,'(EXPONENTIAL FORM)'                                       027710
      PRINT*,'UTILITY=B0+B1*EXP(ATTRIBUTE LEVEL)'                       027720
      ENDIF                                                             027730
      CALL PICTUR(I)                                                    027740
    2 PRINT*,' '                                                        027750
      PRINT*,'DOES THE ABOVE REPRESENTATION APPEAR REASONABLE? (Y/N)'   027760
      PRINT*,'     ?'                                                   027770
      READ(*,'(A1)')CH                                                  027780
      IF((CH.NE.'Y').AND.(CH.NE.'N'))THEN                               027790
      PRINT*,'YOU MUST ENTER "Y" OR "N"'                                027800
      GO TO 2                                                           027810
      ENDIF                                                             027820
      IF(CH.EQ.'N')GO TO 1                                              027830
   10 CONTINUE                                                          027840
      RETURN                                                            027850
      END                                                               027860
```

** Appendix A-3 **

```
      SUBROUTINE UPI                                                    027870
                                                                        027880
                                                                        027890
*****************************************************************     027900
*                                                                       027910
*                                                                       027920
*  THIS ROUTINE CONDUCTS A TEST OF MUTUAL UTILITY INDEPENDENCE BY       *027930
*  CONDUCTING TESTS OF PAIRWISE PREFERENTIAL AND INDEPENDENCE FOR       *027940
*  A SELECTED ATTRIBUTE WITH RESPECT TO THE OTHER ATTRIBUTES.           *027950
*                                                                       *027960
*                                                                       *027970
*  CALLED BY:  ROAT                                                     *027980
*                                                                       *027990
*                                                                       *028000
*  VARIABLES                                                            *028010
*        USED:  NATT                                                    *028020
*                                                                       *028030
*        MODIFIED:  ATTR1,ATTR2,BAND,CH,D1,DEL1,I,                      * 028040
*                   INDEP,ITCL,J,K,MAX1,MAX2,MIN1,MIN2                  *028050
*                   TEMP,TEMP1,TEMP2,TOLER,TOTHER                       *028060
*                                                                       *028070
*                                                                       *028080
*****************************************************************     028090
                                                                        028100
                                                                        028110
      COMMON/ATTR/ATT                                                   028120
      COMMON/P/UTILS                                                    028130
      DATA                                                              028140
      CHARACTER*1 ATTR1,ATTR2,TOTHER,ATT1,DEP,CH*1                      028150
```

```
      REAL BAND(3,2),MAX1,MIN1,MAX2,MIN2
      INTEGER NAU
     IF(NATT.LE.2)CALL UTIL
     IF(NATT.LE.2)GO TO 100
      INDERR=0
      PRINT*,' '
      PRINT*,'AT WHAT TOLERANCE DO YOU WANT TO CHECK YOUR'
      PRINT*,'RESPONSE', USER ,' (PLUS OR MINUS X PERCENT)?'
      PRINT*,'      X=?'
      READ(*,'(I2)')ITOL
      TOLER=FLOAT(ITOL)/100.0
      PRINT*,'WE ARE WORKING AT PLUS OR MINUS ',ITOL,' PERCENT'
    9 PRINT*,USER,' WHICH ATTRIBUTE DO YOU WISH TO EXPLORE THE'
      PRINT*,'UTILITY INDEPENDENCE OF?  (IF YOU WISH TO REVIEW'
      PRINT*,'THE ATTRIBUTES IN THE ORDER THEY WERE INPUT,'
      PRINT*,'ENTER 1000, OTHERWISE ENTER THE ATTRIBUTE NUMBER NOW.)'
      READ(*,'(I4)')NAU
      IF(NAU.NE.1000)GO TO 11
     PRINT*,' '
     PRINT*,'ATTRIBUTE  NUMBER'
      DO 10 I=1,NATT
      PRINT*,'  '
      PRINT*,ATT1(I),'    ',I
   10 CONTINUE
   11 IF(NAU.GT.NATT)GO TO 9
      ATTR1=ATT1(NAU)
      MAX1=AMAX1(ATT(NAU,2),ATT(NAU,3))
     MIN1=AMIN1(ATT(NAU,2),ATT(NAU,3))
      DEL1=(MAX1-MIN1)/10.0
      DO 20 J=1,NATT
      IF(J.EQ.NAU)GO TO 20
      ATTR2=ATT1(J)
      MAX2=AMAX1(ATT(J,2),ATT(J,3))
      MIN2=AMIN1(ATT(J,2),ATT(J,3))
      DEL2=(MAX2-MIN2)/10.0
      PRINT*,' '
      PRINT*,'SUPPOSE THAT THE FOLLOWING'
      PRINT*,'ATTRIBUTES ARE AT THESE LEVELS:'
      DO 30 K=1,NATT
      IF((K.EQ.NAU).OR.(K.EQ.J))GO TO 30
      TOTHER=ATT1(K)
      TEMP=((ATT(K,3)-ATT(K,2))*.25+ATT(K,2))
      PRINT*,TOTHER,' = ',TEMP
   30 CONTINUE
      PRINT*,'THAT IS AT THE 25 PERCENT LEVEL'
    1 PRINT*,' '
      TEMP1=MAX1-5.0*DEL1
      D1=TEMP1*TOLER
      TEMP2=MAX2-5.0*DEL2
      PRINT*,'NOW SUPPOSE THAT YOU HAVE THE INITIAL CONDITIONS:'
      PRINT*,ATTR1,'=',TEMP1,' AND ',ATTR2,'=',TEMP2
      PRINT*,' '
      TEMP2=TEMP2-DEL2*3.
      PRINT*,'IMAGINE THAT ',ATTR2,' IS CHANGED TO ',TEMP2
      PRINT*,'WHAT LEVEL OF ',ATTR1,' WOULD KEEP YOU AS SATISFIED'
      PRINT*,'AS YOU WERE UNDER THE INITIAL CONDITIONS?'
      PRINT*,'(REMEMBER THAT ALL OTHER ATTRIBUTES ARE AT'
      PRINT*,'THE 25 PERCENT LEVEL)'
```

```
      PRINT*,'     ?'                                                        028740
      READ(*,'(F10.0)')TEMP1                                                 028750
      IF((TEMP1.LT.MIN1).OR.(TEMP1.GT.MAX1))THEN                             028760
      PRINT*,'THE INPUT LEVEL OF ',TEMP1                                     028770
      PRINT*,'IS OUTSIDE THE GIVEN RANGE OF ',ATT(I,2),' TO ',ATT(1,3)       028780
      GO TO 1                                                                028790
      ENDIF                                                                  028800
      BAND(1,1)=TEMP1+D1                                                     028810
      BAND(1,2)=TEMP1-D1                                                     028820
      TEMP1=MAX1-5.0*DEL1                                                    028830
      TEMP2=MAX2-5.0*DEL2                                                    028840
2     PRINT*,' '                                                             028850
      PRINT*,'SUPPOSE THAT YOU ARE STARTING AT'                              028860
      PRINT*,ATTR1,'=',TEMP1,' AND ',ATTR2,'=',TEMP2                         028870
      PRINT*,' '                                                             028880
      TEMP2=TEMP2+3.0*DEL2                                                   028890
      PRINT*,'IMAGINE THAT ',TEMP2,' IN ',ATTR2,' IS ACHIEVED.'              028900
      PRINT*,'TO WHAT LEVEL WOULD YOU CHANGE ',ATTR1,' IN ORDER TO'          028910
      PRINT*,'REMAIN AS SATISFIED AS YOU WERE INITIALLY?'                    028920
      PRINT*,'(REMEMBER THAT ALL OTHER ATTRIBUTES ARE AT THE'                028930
      PRINT*,'25 PERCENT LEVEL)'                                             028940
      PRINT*,'     ?'                                                        028950
      READ(*,'(F10.0)')TEMP1                                                 028960
      IF((TEMP1.LT.MIN1).OR.(TEMP1.GT.MAX1))THEN                             028970
      PRINT*,'THE INPUT LEVEL OF ',TEMP1                                     028980
      PRINT*,'IS OUTSIDE THE GIVEN RANGE OF ',ATT(I,2),' TO ',ATT(I,3)       028990
      GO TO 2                                                                029000
      ENDIF                                                                  029010
      BAND(2,1)=TEMP1+D1                                                     029020
      BAND(2,2)=TEMP1-D1                                                     029030
      PRINT*,USER,', SUPPOSE NOW THAT THE FOLLOWING ATTRIBUTES'              029040
      PRINT*,'ARE SHIFTED TO THESE LEVELS:'                                  029050
      DO 40 K=1,NATT                                                         029060
      IF ((K.EQ.MAL).OR.(K.EQ.J))GO TO 40                                    029070
      OTHER=ATT1(K)                                                          029080
      TEMP=((ATT(K,3)-ATT(K,2))*.75+ATT(K,2))                                029090
      PRINT*,'OTHER',,'=',TEMP                                               029100
40    CONTINUE                                                               029110
      PRINT*,'THAT IS AT THE 75 PERCENT LEVEL'                               029120
3     PRINT*,' '                                                             029130
      TEMP1=MAX1-5.0*DEL1                                                    029140
      TEMP2=MAX2-5.0*DEL2                                                    029150
      PRINT*,'SUPPOSE THAT YOU HAVE'                                         029160
      PRINT*,ATTR1,'=',TEMP1,' AND ',ATTR2,'=',TEMP2                         029170
      PRINT*,' '                                                             029180
      TEMP2=TEMP2-3.0*DEL2                                                   029190
      PRINT*,'IMAGINE THAT THE LEVEL OF ',ATTR2                              029200
      PRINT*,'IS CHANGED TO ',TEMP2,'.'                                      029210
      PRINT*,'WOULD THE LEVEL OF ',ATTR1,' NEEDED TO REMAIN'                 029220
      PRINT*,'AS SATISFIED AS AT THE INITIAL CONDITIONS'                     029230
      PRINT*,'LIE BETWEEN ',BAND(1,1),' AND ',BAND(1,2)                      029240
      PRINT*,' (Y/ )  ?'                                                     029250
      READ(*,'(A1)')CH                                                       029260
      IF((CH.EQ.'Y').AND.(CH.NE.' '))THEN                                    029270
      PRINT*,'ONLY "Y" OR " " IS ALLOWED. ',USER                             029280
      GO TO 3                                                                029290
      ENDIF                                                                  029300
```

```
      IF(CH.EQ.'N')INDERR=1
4     PRINT*,' '
      TEMP1=MAX1-5.0*DEL1
      TEMP2=MAX2-5.0*DEL2
      PRINT*,'SUPPOSE THAT YOU HAVE THE INITAL CONDITIONS:'
      PRINT*,ATTR1,'=',TEMP1,' AND ',ATTR2,'=',TEMP2
      PRINT*,' '
      TEMP2=TEMP2+3.0*DEL2
      PRINT*,'IMAGINE THAT YOU MUST ACCEPT'
      PRINT*,'A LEVEL OF ',TEMP2,' IN ',ATTR2
      PRINT*,'WOULD THE LEVEL OF ',ATTR1
      PRINT*,'THAT YOU WOULD HAVE TO MOVE TO (IN ORDER TO BE AS'
      PRINT*,'SATISFIED AS UNDER THE INITAL CONDITIONS) LIE'
      PRINT*,'BETWEEN ',BAND(2,1),' AND ',BAND(2,2)
      PRINT*,' (Y/N)  ?'
      READ(*,'(A1)')CH
      IF((CH.NE.'Y').AND.(CH.NE.'N'))THEN
      PRINT*,USER,', YOU MUST ENTER "Y" OR "N"'
      GO TO 4
      ENDIF
      IF(CH.EQ.'N')INDERR=1
      IF(INDERR.EQ.0)THEN
      PRINT*,'THERE ARE NO INDEPENDENCE PROBLEMS'
      PRINT*,'WITH THE ATTRIBUTES TESTED SO FAR,'
5     PRINT*,'DO YOU WISH TO ASSUME MPI FOR THE'
      PRINT*,'REMAINING ATTRIBUTES? (Y/N)'
      PRINT*,'                ?'
      READ(*,'(A1)')CH
      IF((CH.NE.'N').AND.(CH.NE.'Y'))THEN
      PRINT*,'PLEASE ENTER "Y" OR "N"'
      GO TO 5
      ENDIF
      IF(CH.EQ.'N')THEN
6     PRINT*,'EVEN IF YOU DO NOT WISH TO ASSUME'
      PRINT*,'MPI AMOUNG THE ATTRIBUTES.'
      PRINT*,'DO YOU WANT TO STOP MUI TESTING?  (Y/N).'
      PRINT*,'                ?'
      READ(*,'(A1)')CH
      IF((CH.NE.'N').AND.(CH.NE.'Y'))THEN
      PRINT*,'PLEASE ENTER "Y" OR "N".'
      GO TO 6
      ENDIF
      ENDIF
      IF(CH.EQ.'Y')GO TO 7
      ELSE
      PRINT*,'THERE ARE INDEPENDENCE PROBLEMS'
      PRINT*,'AMOUNG THE ATTRIBUTES ALREADY TESTED.'
8     PRINT*,'DO YOU WISH TO STOP MUI TESTING? (Y/N)'
      PRINT*,'                ?'
      READ(*,'(A1)')CH
      IF((CH.NE.'N').AND.(CH.NE.'Y'))THEN
      PRINT*,'PLEASE ENTER "Y" OR "N"'
      GO TO 8
      ENDIF
      IF(CH.EQ.'Y')GO TO 17
      ENDIF
20    CONTINUE
```

```
17    IF(INDERR.EQ.0)THEN
      PRINT*,'SINCE ',ATT1(NAU),' IS PAIRWISE PREFERENTIALLY'
      PRINT*,'INDEPENDENT OF THE OTHER ATTRIBUTES, ATTRIBUTE '
      PRINT*,ATT1(NAU),'WILL NOW BE TESTED FOR UTILITY INDEPENDENCE.'
      ENDIF
      IF(INDERR.NE.0)THEN
      PRINT*,'THERE ARE INDEPENDENCE PROBLEMS'
      PRINT*,'AMOUNG THE ATTRIBUTES (MPI DOES'
      PRINT*,'NOT HOLD).  DO YOU WISH TO'
      PRINT*,'CONTINUE THE ANALYSIS WITH AN'
      PRINT*,'ADDITIVE UTILITY FUNCTION? (Y/N)'
      PRINT*,'      ?'
      READ(*,'(A1)')CH
      IF(CH.EQ.'Y')CALL UTIL
      ENDIF
51    ATTR1=ATT1(NAU)
      MAX1=AMAX1(ATT(NAU,2),ATT(NAU,3))
      MIN1=AMIN1(ATT(NAU,2),ATT(NAU,3))
      DEL1=(MAX1-MIN1)/10.0
      PRINT*,' '
      PRINT*,'WITH THE OTHER ATTRIBUTES EXCEPT ',ATTR1
      PRINT*,'SET AS THE FOLLOWING LEVELS'
      PRINT*,' '
      DO 60 K=1,NATT
      IF(K.EQ.NAU)GO TO 60
      TOTHER=ATT1(K)
      TEMP=(ATT(K,3)-ATT(K,2))*.25+ATT(K,2)
      PRINT*,TOTHER,' = ',TEMP
60    CONTINUE
      TEMP=(ATT(K,3)-ATT(K,2))*.25+ATT(K,2)
      TEMP1=MAX1-5.0*DEL1
      D1=TEMP1*TOLER
      PRINT*,' '
      PRINT*,'NOW WHAT VALUE OF ATTRIBUTE ',ATTR1,'WITH CERTAINTY'
      PRINT*,'WOULD YOU TRADE FOR A LOTTERY OF A 50-50 CHANCE OF'
      PRINT*,'RECEIVING EITHER ',MAX1,' UNITS OF ',MIN1,' UNITS OF'
      PRINT*,'ATTRIBUTE ',ATTR1
      PRINT*,'      ?'
      READ(*,'(F10.0)')TEMP2
      IF((TEMP1.LT.MIN1).OR.(TEMP1.GT.MAX1))THEN
      PRINT*,'THE INPUT LEVEL OF ',TEMP1
      PRINT*,'IS OUTSIDE THE RANGE OF ',ATT(I,2),' TO ',ATT(I,3)
      GO TO 51
      ENDIF
      TEMP1=TEMP2
      BAND(1,1)=TEMP1+D1
      BAND(1,2)=TEMP1-D1
52    PRINT*,' '
      PRINT*,'NOW WHAT VALUE OF ATTRIBUTE ',ATTR1,'WITH CERTAINTY'
      PRINT*,'WOULD YOU TRADE FOR A LOTTERY OF A 50-50 CHANCE OF'
      PRINT*,'RECEIVING EITHER ',MAX1,' UNITS OF ',TEMP2,' UNITS OF'
      PRINT*,'ATTRIBUTE ',ATTR1
      PRINT*,'      ?'
      READ(*,'(F10.0)')TEMP3
      IF((TEMP3.LT.TEMP2).OR.(TEMP3.GT.MAX1))THEN
      PRINT*,'THE INPUT LEVEL OF ',TEMP3
      PRINT*,'IS OUTSIDE THE RANGE OF ',TEMP2,' TO ',MAX1
```

```
      GO TO 52                                                          030450
      ENDIF                                                             030460
      TEMP1=TEMP3                                                       030470
      BAND(2,1)=TEMP1+D1                                                030480
      BAND(2,2)=TEMP1-D1                                                030490
53    PRINT*,' '                                                        030500
      PRINT*,'NOW WHAT VALUE OF ATTRIBUTE ',ATTR1,'WITH CERTAINTY'      030510
      PRINT*,'WOULD YOU TRADE FOR A LOTTERY OF A 50-50 CHANCE OF'       030520
      PRINT*,'RECEIVING EITHER ',TEMP2,' UNITS OR ',MIN1,' UNITS OF'    030530
      PRINT*,'ATTRIBUTE ',ATTR1                                         030540
      PRINT*,'      ?'                                                  030550
      READ(*,'(F10.0)')TEMP4                                            030560
      IF((TEMP4.LT.MIN1).OR.(TEMP4.GT.TEMP2))THEN                       030570
      PRINT*,'THE INPUT LEVEL OF ',TEMP4                                030580
      PRINT*,'IS OUTSIDE THE RANGE OF ',MIN1,' TO ',TEMP2               030590
      GO TO 53                                                          030600
      ENDIF                                                             030610
      TEMP1=TEMP4                                                       030620
      BAND(3,1)=TEMP1+D1                                                030630
      BAND(3,2)=TEMP1-D1                                                030640
      PRINT*,' '                                                        030650
      PRINT*,USER,', SUPPOSE NOW THAT THE FOLLOWING ATTRIBUTES'         030660
      PRINT*,'ARE SHIFTED TO THESE LEVELS:'                             030670
      PRINT*,' '                                                        030680
      DO 70 K=1,NATT                                                    030690
      IF(K.EQ.NAU)GO TO 70                                              030700
      TOTHER=ATT1(K)                                                    030710
      TEMP=(ATT(K,3)-ATT(K,2))*.75+ATT(K,2)                             030720
      PRINT*,TOTHER,'=',TEMP                                            030730
      CONTINUE                                                          030740
      PRINT*,'THAT IS AT THE 75 PERCENT LEVEL'                          030750
73    PRINT*,' '                                                        030760
      PRINT*,'NOW FOR THE LOTTERY OF A 50-50 CHANCE OF RECEIVING EITHE  030770
      PRINT*,'AX1,' UNITS OR ',MIN1,' UNITS OF ATTRIBUTE ',ATTR1        030780
      PRINT*,'WOULD YOU TRADE FOR A VALUE OF ATTRIBUTE ',ATTR1,' WITH'  030790
      PRINT*,'CERTAINTY BETWEEN ',BAND(1,1),' UNITS AND ',BAND(1,2)     030800
      PRINT*,'UNITS,  (Y/N)?'                                           030810
      READ(*,'(A1)')CH                                                  030820
      IF((CH.NE.'Y').AND.(CH.NE.'N'))THEN                               030830
      PRINT*,'ONLY "Y" OR "N" IS ALLOWED, ',USER                        030840
      GO TO 73                                                          030850
      ENDIF                                                             030860
      IF(CH.EQ.'N')INDEX=1                                              030870
74    PRINT*,' '                                                        030880
      PRINT*,'NOW FOR THE LOTTERY OF A 50-50 CHANCE OF RECEIVING EITHE  030890
      PRINT*,'AX1,' UNITS OR ',TEMP2,' UNITS OF ATTRIBUTE ',ATTR1       030900
      PRINT*,'WOULD YOU TRADE FOR A VALUE OF ATTRIBUTE ',ATTR1,' WITH'  030910
      PRINT*,'CERTAINTY BETWEEN ',BAND(2,1),' UNITS AND ',BAND(2,2)     030920
      PRINT*,'UNITS,  (Y/N)'                                            030930
      READ(*,'(A1)')CH                                                  030940
      IF((CH.NE.'Y').AND.(CH.NE.'N'))THEN                               030950
      PRINT*,'ONLY "Y" OR "N" IS ALLOWED, ',USER                        030960
      GO TO 74                                                          030970
      ENDIF                                                             030980
      IF(CH.EQ.'N')INDEX=1                                              030990
      PRINT*,' '                                                        031000
      PRINT*,' NOW FOR THE LOTTERY OF A 50-50 CHANCE OF RECEIVING EITHE 031010
```

```
      PRINT*,TEMP2,' UNITS OR ',MIN1,' UNITS OF ATTRIBUTE, ',ATTR1
      PRINT*,'WITH CERTAINTY BETWEEN ',BAND(3,1),' UNITS AND ',BAND(3,2)
      PRINT*,'UNITS.  (Y/N)'
      READ(*,'(A1)')CH
      IF((CH.NE.'Y').AND.(CH.NE.'N'))THEN
      PRINT*,'ONLY "Y" OR "N" IS ALLOWED, ',USER
      GO TO 75
      ENDIF
      IF(CH.EQ.'N')INDERR=1
7     IF(INDERR.EQ.0)THEN
      PRINT*,' '
      PRINT*,' '
      PRINT*,'  THE ATTRIBUTES ARE UTILITY INDEPENDENT'
      PRINT*,' '
      PRINT*,' '
      CALL UTIL
      ELSE
      PRINT*,'THERE ARE INDEPENDENCE PROBLEMS'
      PRINT*,'AMONG THE ATTRIBUTES (MUI DOES'
      PRINT*,'NOT HOLD).  DO YOU WISH TO'
      PRINT*,'CONTINUE THE ANALYSIS WITH AN'
      PRINT*,'ADDITIVE UTILITY FUNCTION?  (Y/N)'
      PRINT*,'        ?'
      READ(*,'(A1)')CH
      IF(CH.EQ.'Y')CALL UTIL
      ENDIF
100   RETURN
      END
```

** Appendix A-4 **

```
      SUBROUTINE RCV

*****************************************************************
*                                                               *
*                                                               *
*  THIS ROUTINE ELICITS THE ATTRIBUTE LEVELS OF THE             *
*  ALTERNATIVE SYSTEMS ACROSS ALL THE DATA NODES.               *
*                                                               *
*                                                               *
*  CALLED BY:  WVLOD1                                           *
*                                                               *
*  VARIABLES                                                    *
*        USED:  IFIND,NATT,NSYS,OBJCTV                          *
*                                                               *
*        MODIFIED:  ANSWER,I,II,J,XMAX,XMIN                     *
*                                                               *
*                                                               *
*****************************************************************

      COMMON/ATTR/NATT
      COMMON/LEVEL/NLVLS,[illegible] (20),IFIND,NDIFF,IFADD,LVL,LEVEL(20,3)
```

```
      COMMON/MEX/ICONT,IDATA,ITOTL                                      039620
      COMMON/SYS1/NSYS                                                  039630
      SAVE                                                              039640
      CHARACTER*1 LABEL,OBJCTV(16),SYSLBL,ATT1                          039650
      PRINT*,'WE ARE AT THE DATA MODE:'                                 039660
      CALL OBJECT(IFIND,OBJCTV)                                         039670
      II=1                                                              039680
      DO 5 I=1,4                                                        039690
      WRITE(*,'(1X,4A1)')(OBJCTV(K),K=II,II+3)                          039700
      II=II+4                                                           039710
    5 CONTINUE                                                          039720
      PRINT*,'WHICH HAS THE ASSOCIATED ATTRIBUTE ',LABEL(IFIND)         039730
      DO 10 I=1,NSYS                                                    039740
      DO 30 J=1,NATT                                                    039750
      IF(LABEL(IFIND).EQ.ATT1(J))THEN                                   039760
      PCHECK=ATT(J,1)                                                   039770
      GO TO 31                                                          039780
      ENDIF                                                             039790
   30 CONTINUE                                                          039800
   31 IF(PCHECK.EQ.0.0)THEN                                             039810
      PRINT*,' '                                                        039820
      PRINT*,'THE CURRENT LEVEL OF THE ATTRIBUTE ',LABEL(IFIND)         039830
      PRINT*,'IS ',XLEVEL(VRAY(IFIND,I),LABEL(IFIND)),' FOR SYSTEM'     039840
      PRINT*,SYSLBL(I)                                                  039850
      PRINT*,' '                                                        039860
      PRINT*,'THE RANGE OF THE ATTRIBUTE IS ',ATT(J,2),' TO ',ATT(J,3)  039870
      XMIN=AMIN1(ATT(J,2),ATT(J,3))                                     039880
      XMAX=AMAX1(ATT(J,2),ATT(J,3))                                     039890
      PRINT*,' '                                                        039900
      PRINT*,'WHAT IS THE NEW LEVEL (REAL NUMBER)?'                     039910
      READ(*,'(F10.4)')ANSWER                                           039920
      IF((ANSWER.LT.XMIN).OR.(ANSWER.GT.XMAX))THEN                      039930
      PRINT*,'THE LEVEL OF ',ANSWER,' IS OUT OF RANGE.'                 039940
      GO TO 1                                                           039950
      ENDIF                                                             039960
      ELSE                                                              039970
      DELTA=ABS(ATT(J,2)-ATT(J,3))/10.                                  039980
      MIN=10*(I-1)+4                                                    039990
   11 X=AMIN1(ATT(J,2),ATT(J,3))                                        040000
      SUM=0.0                                                           040010
      INDEX=MIN-1                                                       040020
      DO 32 K=1,9                                                       040030
      X=X+DELTA                                                         040040
      INDEX=INDEX+1                                                     040050
      PRINT*,' '                                                        040060
      PRINT*,'THE CURRENT SPIKE PROBABILITY (SEE '                      040070
      PRINT*,'USER''S MANUAL) FOR ',LABEL(IFIND)                        040080
      PRINT*,'AT A LEVEL OF ',X,' IS ',ATT(J,INDEX)                     040090
    2 PRINT*,' '                                                        040100
      PRINT*,'WHAT IS THE NEW SPIKE PROBABILITY'                        040110
      PRINT*,'      ?'                                                  040120
      READ(*,'(F10.4)')P                                                040130
      IF((P.LT.0.0).OR.(P.GT.1.0))THEN                                  040140
      PRINT*,'THE INPUT VALUE OF ',P                                    040150
      PRINT*,'IS OUTSIDE THE RANGE OF (0.0,1.0)'                        040160
      PRINT*,'PLEASE RECONSIDER THE QUESTION'                           040170
```

```
      GO TO 2                                                          040180
      ENDIF                                                            040190
      SUM=SUM+PROB                                                     040200
      IF((SUM.GT.1.02).OR.((K.EQ.9).AND.(SUM.LT..98)))THEN             040210
      PRINT*,' '                                                       040220
      PRINT*,'THE INPUT SPIKE PROBABILITIES DO NOT'                    040230
      PRINT*,'SUM TO 1.0, THEY SUM TO ',SUM                            040240
      PRINT*,'REINPUT THE SPIKE PROBABILITIES'                         040250
      GO TO 11                                                         040260
      ENDIF                                                            040270
      CALL ATTVAL(J,INDEX,PROB)                                        040280
32    CONTINUE                                                         040290
      CALL DRWPRB(J,MIN,LABEL(IFIND))                                  040300
      ANSWER=CONVLT(J,MIN,LABEL(IFIND))                                040310
      GO TO 99                                                         040320
      ENDIF                                                            040330
      ANSWER=VALU(ANSWER,LABEL(IFIND))                                 040340
99    IF((ANSWER.LT.0.0).OR.(ANSWER.GT.1.0))THEN                       040350
      ANSWER=AMIN1(ANSWER,1.0)                                         040360
      ANSWER=AMAX1(ANSWER,0.0)                                         040370
      PRINT*,'THE INPUT ATTRIBUTE LEVEL CAUSES'                        040380
      PRINT*,'THE VALUE GENERATED (BASED ON THE'                       040390
      PRINT*,'ESTIMATED INDIVIDUAL VALUE FUNCTION)'                    040400
      PRINT*,'TO BE OUTSIDE THE RANGE (0.0 - 1.0).'                    040410
      PRINT*,'IN ORDER TO REMAIN IN THE PROPER RANGE,'                 040420
      PRINT*,'YOUR INPUT VALUE IS BEING CHANGED TO'                    040430
      PRINT*,XLEVEL(ANSWER,LABEL(IFIND))                               040440
      PRINT*,'IF THIS IS UNACCEPTABLE, USE ***ATT***'                  040450
      PRINT*,'TO ADJUST THE VALUE FUNCTION, AFTER'                     040460
      PRINT*,'EXITTING THIS OPTION.'                                   040470
      ENDIF                                                            040480
      CALL VSET(IFIND,I,ANSWER)                                        040490
10    CONTINUE                                                         040500
      PRINT*,' '                                                       040510
      PRINT*,'ENTER COMMENTS ON THESE ENTRIES.'                        040520
      CALL CSET(IFIND)                                                 040530
      RETURN                                                           040540
      END                                                              040550
```

** Appendix A-5 **

```
      FUNCTION CONVLT(J,MIN,ATTRIB)                                    037920
      CHARACTER*10 ATTRIB                                              037930
      INDEX=MIN+1                                                      037940
      DELTA=ABS(ATT(J,2)-ATT(J,3))/10.                                 037950
      CONVLT=0.0                                                       037960
      X=AMIN1(ATT(J,2),ATT(J,3))                                       037970
      DO 10 I=1,9                                                      037980
      X=X+DELTA                                                        037990
      INDEX=INDEX+1                                                    038000
      CONVLT=CONVLT+VALU(X,ATTRIB)*ATT(J,INDEX)                        038010
10    CONTINUE                                                         038020
      RETURN                                                           038030
      END                                                              038040
```

```
      SUBROUTINE DRWPRP(J,MIN,ATTRIB)                                   03 050
      CHARACTER*10 ATTRIB,DUMMY(50)*1                                   03 060
      PRINT*,' '                                                        03B070
      PRINT*,'THE SPIKE PROBABILITIES RESULT IN THE '                   03B080
      PRINT*,'FOLLOWING PLOT:'                                          03B090
      PRINT*,' '                                                        03 100
      PRINT*,'          0.0       0.2       0.4       0.6       0.8'  03 110
      PRINT*,'           +---------+---------+---------+---------+---' 03 120
      DELTA=ABS(ATT(J,2)-ATT(J,3))/10.0                                 03 130
      X=AMIN1(ATT(J,2),ATT(J,3))                                        03B140
      INDEX=MIN-1                                                       03B150
      DO 10 I=0,9                                                       03 160
      X=X+DELTA                                                         03B170
      DO 1 K=1,50                                                       03B180
1     DUMMY(K)=' '                                                      03B190
      INDEX=INDEX+1                                                     03B200
      ISTOP=INT(ATT(J,INDEX)/.02)                                       03B210
      DO 20 II=1,ISTOP                                                  03B220
      DUMMY(II)='*'                                                     03B230
20    CONTINUE                                                          03B240
      WRITE(*,'(1X,F10.4,50A1)')X,(DUMMY(II),II=1,50)                   03B250
10    CONTINUE                                                          03B260
      PRINT*,'           +---------+---------+---------+---------+---' 03B270
      PRINT*,'           0.0       0.2       0.4       0.6       0.8' 03B290
      PRINT*,' '                                                        03B290
      PRINT*,'SPIKE PROBABILITIES FOR ATTRIBUTE ',ATTRIB                03 300
      PRINT*,'(Y-AXIS IS ATTRIBUTE LEVEL)'                              03 310
      PRINT*,' '                                                        03B320
      RETURN                                                            03 330
      END                                                               03 340
```

Appendix B

R and D Funds Allocation Example

```
WHAT IS YOUR NAME, PLEASE? aaron d.
THANK YOU,  AARON D. .  WE WILL NOW BEGIN THE
DECISION ANALYSIS.

OPENING FILE NUMBER 1
IS THIS DATA NEW (N) OR STORED (S)?n




 AARON D. ,YOUR OPTIONS ARE:
ATT COP DIS DON MOD NEW NUM PRU REV SEL
SEN SPA STA SYS TTL WVC
◆◆◆NOTE: IF YOU NEED AN EXPLANATION,  AARON D.
TYPE "HELP" ◆◆◆

WHAT IS YOUR CHOICE,  AARON D. ?new

THE FOLLOWING INFORMATION WILL ALLOW YOU TO CHOOSE
AN EXISTING (STORED) DATA FILE, OR TO CONSTRUCT A
NEW ONE,  AARON D. .

THE CURRENT TREE IS NUMBER 1

WITH WHICH TREE WOULD YOU LIKE TO WORK,  AARON D. ?1

OPENING FILE NUMBER 1
IS THIS DATA NEW (N) OR STORED (S)?n

FILE 1 HAS NO CURRENT TREE STRUCTURE.  YOU ARE
BEING TRANSFERRED TO OPTION ◆◆◆ NEW ◆◆◆.




YOU ARE AT THE POINT WHERE YOU WILL BE ENTERING
THE ALTERNATIVE SYSTEMS WHICH WILL BE RANKED
IN TERMS OF PREFERENCE.  PLEASE CHOOSE THE
APPROPRIATE OPTION.

   A(DD      D(ELETE      N(EW      E(XIT
     ?n
```

```
ENTER...SYSTEM 1 LABEL
(10 LETTERS OR LESS)
    ?project s

ENTER...SYSTEM 2 LABEL
(10 LETTERS OR LESS)
    ?project t

ENTER...SYSTEM 3 LABEL
(10 LETTERS OR LESS)
    ?project x

ENTER...SYSTEM 4 LABEL
(10 LETTERS OR LESS)
    ?project y

ENTER...SYSTEM 5 LABEL
(10 LETTERS OR LESS)
    ?project z

ENTER...SYSTEM 6 LABEL
(10 LETTERS OR LESS)
    ?
```

```
YOU ARE AT THE POINT WHERE YOU WILL BE ENTERING
THE ALTERNATIVE SYSTEMS WHICH WILL BE RANKED
IN TERMS OF PREFEPENCE.  PLEASE CHOOSE THE
APPROPRIATE OPTION.

   A(DD      D(ELETE      N(EW      E(XIT
     ?e
```

```
ENTER A TITLE FOR THIS DATA STRUCTURE...
? research and development
? funds allocation -
? project selection
?
```

```
SPANNING NODES:      "A"=ALL      "S"=SELECT
     ?a



DO YOU WISH TO BUILD A NEW TREE, AARON D. ?      (Y/N)
     ?y

DO YOU WISH TO BY-PASS THE BETWEEN NODE CHECK?n
ADDING DOWNLINKS TO NODE:
 0

 AARON D. , WHAT IS THE NEXT SUBOBJECTIVE?
(USE NO MORE THAN TWO 80 CHARACTER LINES)
? to provide for successful
PLEASE CONTINUE
? r and d efforts
THE LAST SUBOBJECTIVE ENTERED IS:
 TO PROVIDE FOR SUCCESSFUL

 R AND D EFFORTS



CURRENT NUMBER OF NODES: 2(MAX 500)
CURRENT NUMBER OF LEVELS: 2(MAX 20)
CURRENT NUMBER OF SYSTEMS: 5(MAX 59)
ADDING DOWNLINKS TO NODE:
 1
 TO PROVIDE FOR SUCCESSFUL

 R AND D EFFORTS


 AARON D. , WHAT IS THE NEXT SUBOBJECTIVE?
(USE NO MORE THAN TWO 80 CHARACTER LINES)
? to produce significant results
PLEASE CONTINUE
?  from r and d efforts
THE LAST SUBOBJECTIVE ENTERED IS:
 TO PRODUCE SIGNIFICANT RESULTS

  FROM R AND D EFFORTS
```

```
WHICH IS SUBOBJECTIVE NUMBER 1
FOR THE OBJECTIVE:
 TO PROVIDE FOR SUCCESSFUL

 R AND D EFFORTS


CURRENT NUMBER OF NODES: 3(MAX 500)
CURRENT NUMBER OF LEVELS: 2(MAX 20)
CURRENT NUMBER OF SYSTEMS: 5(MAX 59)
ADDING DOWNLINKS TO NODE:
 1  1
 TO PRODUCE SIGNIFICANT RESULTS

  FROM R AND D EFFORTS


 AARON D. , WHAT IS THE NEXT SUBOBJECTIVE?
(USE NO MORE THAN TWO 80 CHARACTER LINES)
? to expand technology base, but not at
PLEASE CONTINUE
? expense of focused r add d efforts
THE LAST SUBOBJECTIVE ENTERED IS:
 TO EXPAND TECHNOLOGY BASE, BUT NOT AT

 EXPENSE OF FOCUSED R AND D EFFORTS


WHICH IS SUBOBJECTIVE NUMBER 1
FOR THE OBJECTIVE:
 TO PRODUCE SIGNIFICANT RESULTS

  FROM R AND D EFFORTS


 AARON D. , WHAT IS THE NEXT SUBOBJECTIVE?
(USE NO MORE THAN TWO 80 CHARACTER LINES)
? to gain sponsorship for funding the
PLEASE CONTINUE
? advanced development of r and d projects
THE LAST SUBOBJECTIVE ENTERED IS:
 TO GAIN SPONSORSHIP FOR FUNDING THE

 ADVANCED DEVELOPMENT OF R AND D PROJECT
S

WHICH IS SUBOBJECTIVE NUMBER 2
FOR THE OBJECTIVE:
 TO PRODUCE SIGNIFICANT RESULTS

  FROM R AND D EFFORTS
```

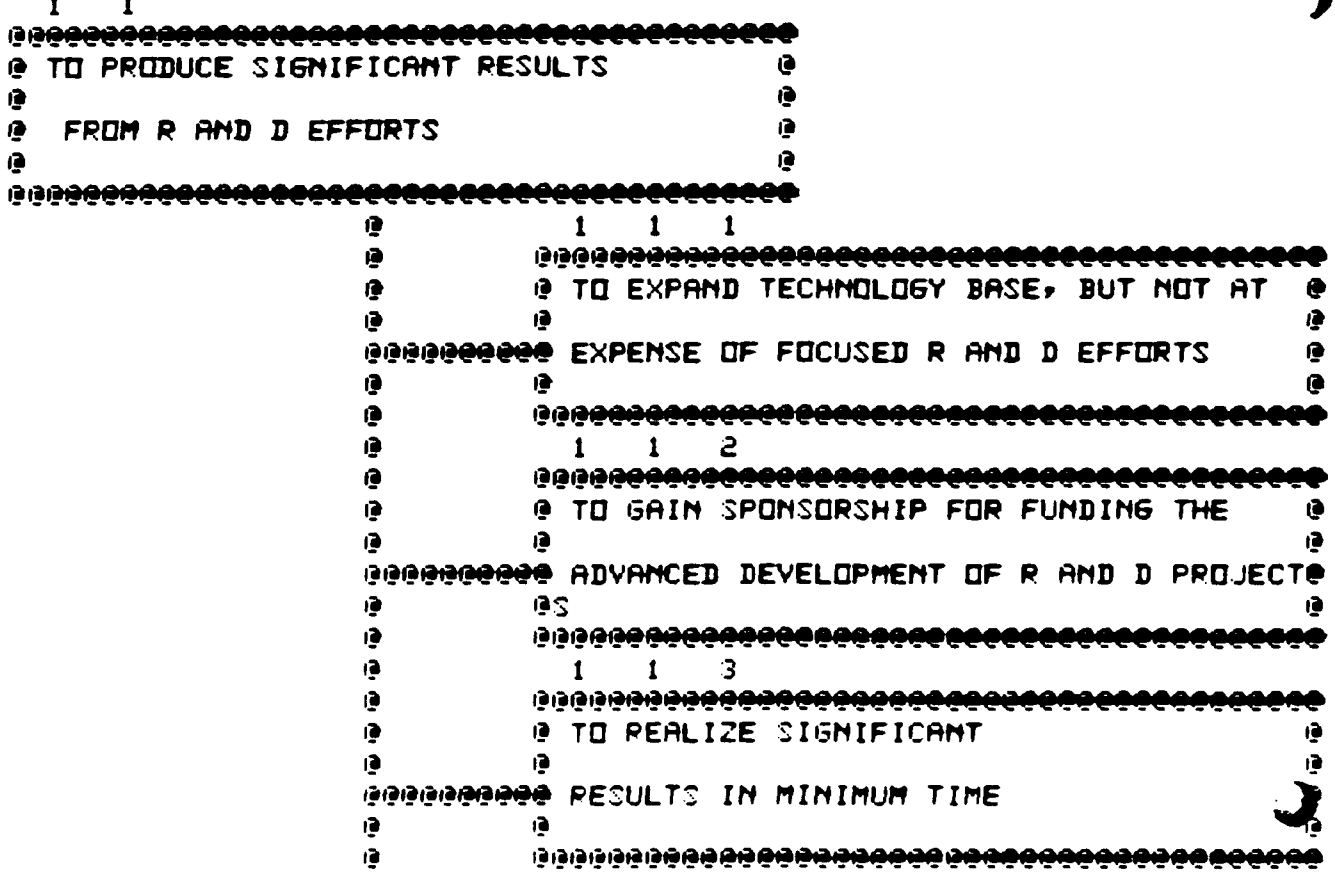
```
 AARON D. , WHAT IS THE NEXT SUBOBJECTIVE?
(USE NO MORE THAN TWO 80 CHARACTER LINES)
? to dealize significant
PLEASE CONTINUE
? results in minimum time
THE LAST SUBOBJECTIVE ENTERED IS:
 TO REALIZE SIGNIFICANT

 RESULTS IN MINIMUM TIME


WHICH IS SUBOBJECTIVE NUMBER 3
FOR THE OBJECTIVE:
 TO PRODUCE SIGNIFICANT RESULTS

  FROM R AND D EFFORTS


 AARON D. , WHAT IS THE NEXT SUBOBJECTIVE?
(USE NO MORE THAN TWO 80 CHARACTER LINES)
?
```



```
 AARON D. , DO THE SUBOBJECTIVES ADDRESS ALL FACETS
OF THE PARENT OBJECTIVE?  (Y/N)
     ?y

IS THERE ANY OVERLAP BETWEEN THE COVERAGES OF
THE SUBOBJECTIVES,  AARON D. ?  (Y/N)
     ?n

 AARON D. , ARE ALL THE SUBOBJECTIVES OPERATIONALLY
MEANINGFUL TO YOU?  (Y/N)
     ?y

COULD ANY OF THE SUBOBJECTIVES BE IGNORED WITHOUT
SIGNIFICANTLY IMPACTING YOUR PREFERENCES,  AARON D. ?  (Y/N)
     ?n



CURRENT NUMBER OF NODES: 6(MAX 500)
CURRENT NUMBER OF LEVELS: 3(MAX 20)
CURRENT NUMBER OF SYSTEMS: 5(MAX 59)
ADDING DOWNLINKS TO NODE:
 1  1  1
 TO EXPAND TECHNOLOGY BASE, BUT NOT AT

 EXPENSE OF FOCUSED R AND D EFFORTS


 AARON D. , WHAT IS THE NEXT SUBOBJECTIVE?
(USE NO MORE THAN TWO 80 CHARACTER LINES)
? to start projects with high probability
PLEASE CONTINUE
? of success in meeting identified needs
THE LAST SUBOBJECTIVE ENTERED IS:
 TO START PROJECTS WITH HIGH PROBABILITY

 OF SUCCESS IN MEETING IDENTIFIED NEEDS


WHICH IS SUBOBJECTIVE NUMBER 1
FOR THE OBJECTIVE:
 TO EXPAND TECHNOLOGY BASE, BUT NOT AT

 EXPENSE OF FOCUSED R AND D EFFORTS
```

```
CURRENT NUMBER OF NODES:  8 (MAX 500)
CURRENT NUMBER OF LEVELS: 4 (MAX 20)
CURRENT NUMBER OF SYSTEMS: 5 (MAX 59)
ADDING DOWNLINKS TO NODE:
 1  1  2
 TO GAIN SPONSORSHIP FOR FUNDING THE

 ADVANCED DEVELOPMENT OF R AND D PROJECT
S

 AARON D. , WHAT IS THE NEXT SUBOBJECTIVE?
(USE NO MORE THAN TWO 80 CHARACTER LINES)
? to start projects with the sponsorship   of major organizations willing to
PLEASE CONTINUE
?commit development funds to successful   r and d projects (number of sponsors)
THE LAST SUBOBJECTIVE ENTERED IS:
 TO START PROJECTS WITH THE SPONSORSHIP
  OF MAJOR ORGANIZATIONS WILLING TO
COMMIT DEVELOPMENT FUNDS TO SUCCESSFUL
 R AND D PROJECTS (NUMBER OF SPONSORS)

WHICH IS SUBOBJECTIVE NUMBER 1
FOR THE OBJECTIVE:
 TO GAIN SPONSORSHIP FOR FUNDING THE

 ADVANCED DEVELOPMENT OF R AND D PROJECT
S

 AARON D. , WHAT IS THE NEXT SUBOBJECTIVE?
(USE NO MORE THAN TWO 80 CHARACTER LINES)
?


CURRENT NUMBER OF NODES:  9 (MAX 500)
CURRENT NUMBER OF LEVELS: 4 (MAX 20)
CURRENT NUMBER OF SYSTEMS: 5 (MAX 59)
ADDING DOWNLINKS TO NODE:
 1  1  2  1
 TO START PROJECTS WITH THE SPONSORSHIP
  OF MAJOR ORGANIZATIONS WILLING TO
COMMIT DEVELOPMENT FUNDS TO SUCCESSFUL
 R AND D PROJECTS (NUMBER OF SPONSORS)
```

```
ADDING DOWNLINKS TO NODE:
 1  1  3
 TO REALIZE SIGNIFICANT

 RESULTS IN MINIMUM TIME


 AARON D. , WHAT IS THE NEXT SUBOBJECTIVE?
(USE NO MORE THAN TWO 80 CHARACTER LINES)
? to start r and d projects with

PLEASE CONTINUE
? minimum time to fruition
THE LAST SUBOBJECTIVE ENTERED IS:
 TO START R AND D PROJECTS WITH

 MINIMUM TIME TO FRUITION


WHICH IS SUBOBJECTIVE NUMBER 1
FOR THE OBJECTIVE:
 TO REALIZE SIGNIFICANT

 RESULTS IN MINIMUM TIME


 AARON D. , PLEASE INPUT AN ATTRIBUTE FOR
THE DATA NODE WITH THE OBJECTIVE:
 TO START R AND D PROJECTS WITH AN
 ESTABLISHED TECHNOLOGY BASE WITH WHICH
 TO MEET IDENTIFIED NEEDS
  (TECHNOLOGY BASE UNITS - TB UNITS)
(10 LETTERS OR LESS)
     ? tb units

IS THE ATTRIBUTE  TB UNITS
SUCH THAT BY KNOWING ITS LEVEL,
THE ATTAINMENT OF THE OBJECTIVE
IS TOTALLY DETERMINED?  (Y/N)
     ?y

COULD THE ATTRIBUTE  TB UNITS
BE CHANGED SO AS TO IMPROVE
COMMUNICATING WHAT IS IMPLIED
IN THE OBJECTIVE?  (Y/N)
     ?n

WILL THIS ATTRIBUTE BE PROBABILISTIC ? (Y/N)
     ?y
```

```
WHAT IS THE WORST ACCEPTABLE
LEVEL (REAL NUMBER) OF  TB UNITS
     ?0
THE LEVEL STORED WAS 0.

WHAT IS THE BEST (REALISTICALLY)
LEVEL (REAL NUMBER) OF  TB UNITS ,  AARON D. ?
     ?10
THE LEVEL STORED WAS 10.

 AARON D. , PLEASE INPUT AN ATTRIBUTE FOR
THE DATA NODE WITH THE OBJECTIVE:
 TO START PROJECTS WITH THE SPONSORSHIP
  OF MAJOR ORGANIZATIONS WILLING TO
COMMIT DEVELOPMENT FUNDS TO SUCCESSFUL
 R AND D PROJECTS (NUMBER OF SPONSORS)
(10 LETTERS OR LESS)
     ?sponsors

IS THE ATTRIBUTE SPONSORS
SUCH THAT BY KNOWING ITS LEVEL,
THE ATTAINMENT OF THE OBJECTIVE
IS TOTALLY DETERMINED?  (Y/N)
     ?y

COULD THE ATTRIBUTE SPONSORS
BE CHANGED SO AS TO IMPROVE .
COMMUNICATING WHAT IS IMPLIED
IN THE OBJECTIVE?  (Y/N)
     ?n

WILL THIS ATTRIBUTE BE PROBABILISTIC ? (Y/N)
     ?y
WHAT IS THE WORST ACCEPTABLE
LEVEL (REAL NUMBER) OF SPONSORS
     ?0
THE LEVEL STORED WAS 0.

WHAT IS THE BEST (REALISTICALLY)
LEVEL (REAL NUMBER) OF SPONSORS  ,  AARON D. ?
     ?10
THE LEVEL STORED WAS 10.

 AARON D. , PLEASE INPUT AN ATTRIBUTE FOR
THE DATA NODE WITH THE OBJECTIVE:
 TO START R AND D PROJECTS WITH

 MINIMUM TIME TO FRUITION

(10 LETTERS OR LESS)
     ?time,years
```

```
IS THE ATTRIBUTE TIME,YEARS
SUCH THAT BY KNOWING ITS LEVEL,
THE ATTAINMENT OF THE OBJECTIVE
IS TOTALLY DETERMINED?  (Y/N)
     ?y

COULD THE ATTRIBUTE TIME,YEARS
BE CHANGED SO AS TO IMPROVE
COMMUNICATING WHAT IS IMPLIED
IN THE OBJECTIVE?  (Y/N)
     ?n

WILL THIS ATTRIBUTE BE PROBABILISTIC ?  (Y/N)
     ?y
WHAT IS THE WORST ACCEPTABLE
LEVEL (RE NUMBER) OF TIME,YEARS
     ?5
THE LEVEL STORED WAS 5.

WHAT IS THE BEST (REALISTICALLY)
LEVEL (REAL NUMBER) OF TIME,YEARS,  AARON D. ?
     ?0
THE LEVEL STORED WAS 0.
 TB UNITS  SPONSORS   TIME,YEARS

THE ABOVE IS THE CURRENT SET OF ATTRIBUTES,  AARON D. .
IF YOU SEE ANY WHICH ARE REDUNDANT, OR
WHICH HAVE A DIRECT IMPACT ON ONE ANOTHER
(E.G. WEIGHT AND THRUST),
YOU SHOULD REFORM THE ATTRIBUTE SET TO
REMOVE THESE PROBLEMS.

DO YOU WISH TO REFORM THE ATTRIBUTE SET,  AARON D. ?
(Y/N)    ?n

DO YOU WISH TO BYPASS INDEPENDENCE TESTING?n

AT WHAT TOLERANCE DO YOU WANT TO CHECK YOUR
RESPONSEAARON D.    (PLUS OR MINUS X PERCENT)?
     X=?10
WE ARE WORKING AT PLUS OR MINUS 10 PERCENT
AARON D.    WHICH ATTRIBUTE DO YOU WISH TO EXPLORE THE
UTILITY INDEPENDENCE OF

UTILITY INDEPENDENCE OF?  (IF YOU WISH TO REVIEW
THE ATTRIBUTES IN THE ORDER THEY WERE INPUT,
ENTER 1000, OTHERWISE ENTER THE ATTRIBUTE NUMBER NOW.)
1000

ATTRIBUTE  NUMBER

TB UNITS      1
```

```
SPONSORS     2

TIME,YEARS   3
AARON D.    WHICH ATTRIBUTE DO YOU WISH TO EXPLORE THE
UTILITY INDEPEND

UTILITY INDEPENDENCE OF?  (IF YOU WISH TO REVIEW
THE ATTRIBUTES IN THE ORDER THEY WERE INPUT,
ENTER 1000, OTHERWISE ENTER THE ATTRIBUTE NUMBER NOW.)1

SUPPOSE THAT THE FOLLOWING
ATTRIBUTES ARE AT THESE LEVELS:
TIME,YEARS = 1.25
THAT IS AT THE 25 PERCENT LEVEL

NOW SUPPOSE THAT YOU HAVE THE INITIAL CONDITIONS:
TB UNITS  =5. AND SPONSORS  =5.

IMAGINE THAT SPONSORS   IS CHANGED TO 2.
WHAT LEVEL OF TB UNITS   WOULD KEEP YOU AS SATISFIED
AS YOU WERE UNDER THE INITIAL CONDITIONS?
(REMEMBER THAT ALL OTHER ATTRIBUTES ARE AT
THE 25 PERCENT LEVEL)
     ?8

SUPPOSE THAT YOU ARE STARTING AT
TB UNITS  =5. AND SPONSORS  =5.

IMAGINE T

IMAGINE THAT 8. IN SPONSORS   IS ACHIEVED.
TO WHAT LEVEL WOULD YOU CHAN

TO WHAT LEVEL WOULD YOU CHANGE TB UNITS   IN ORDER TO
REMAIN AS SATISFIED AS YOU WERE INITIALLY?


(REMEMBER THAT ALL OTHER ATTRIBUTES ARE AT THE
25 PERCENT LEVEL)
     ? 3
AARON D.  , SUPPOSE NOW THAT THE FOLLOWING ATTRIBUTES
ARE SHIFTED

ARE SHIFTED TO THESE LEVELS:
TIME,YEARS=3.75
THAT IS AT THE 75 PERCENT LEVEL

SUPPOSE THAT YOU HAVE
TB UNITS  =5. AND SPONSORS  =5.
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```
IMAGINE THAT THE LEVEL OF SPONSORS
IS CHANGED TO 2..
WOULD THE LEVEL OF TB UNITS   NEEDED TO REMAIN
AS SATISFIED AS AT THE INITIAL CONDITIONS
LIE BETWEEN 8.5 AND 7.5
 (Y/N)  ?y

SUPPOSE THAT YOU HAVE THE INITAL CONDITIONS:
TB UNITS  =5. AND SPONSORS  =5.

IMAGINE THAT YOU MUST ACCEPT


A LEVEL OF 8. IN SPONSORS
WOULD THE LEVEL OF TB UNITS
THAT YOU WOULD HAVE TO MOVE TO (IN ORDER TO BE AS
SATISFIED AS UNDER THE INITAL CONDITIONS) LIE
BETWEEN 3.5 AND 2.5
 (Y/N)  ?y
THERE ARE NO INDEPENDENCE PROBLEMS
WITH THE ATTRIBUTES TESTED SO FAR,
DO YOU WISH TO ASSUME MPI FOR THE
REMAINING ATTRIBUTES? (Y/N)
              ?n
EVEN IF YOU DO NOT WISH TO ASSUME
MPI AMOUNG THE ATTRIBUTES.
DO YOU WANT TO STOP MUI TESTING?  (Y/N).
              ?n

SUPPOSE THAT THE FOLLOWING
ATTRIBUTES ARE AT THESE LEVELS:
SPONSORS    = 2.5
THAT IS AT THE 25 PERCENT LEVEL

NOW SUPPOSE THAT YOU HAVE THE INITIAL CONDITIONS:
TB UNITS  =5. AND TIME,YEARS=2.5

IMAGINE THAT TIME,YEARS IS CHANGED TO 1.
WHAT LEVEL OF TB UNITS   WOULD KEEP YOU AS SATISFIED
AS YOU WERE UNDER THE INITIAL CONDITIONS?
(REMEMBER THAT ALL OTHER ATTRIBUTES ARE AT
THE 25 PERCENT LEVEL)
    ?2

SUPPOSE THAT YOU ARE STARTING AT
TB UNITS  =5. AND TIME,YEARS=2.5

IMAGINE THAT 4. IN TIME,YEARS IS ACHIEVED.
TO WHAT LEVEL WOULD YOU CHANGE TB UNITS   IN ORDER TO
REMAIN AS SATISFIED AS YOU WERE INITIALLY?
(REMEMBER THAT ALL OTHER ATTRIBUTES ARE AT THE
25 PERCENT LEVEL)
     ?8
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```
AARON D.  , SUPPOSE NOW THAT THE FOLLOWING ATTRIBUTES
ARE SHIFTED TO THESE LEVELS:
SPONSORS  =7.5
THAT IS AT THE 75 PERCENT LEVEL

SUPPOSE THAT YOU HAVE
TB UNITS  =5. AND TIME,YEARS=2.5

IMAGINE THAT THE LEVEL OF TIME,YEARS
IS CHANGED TO 1..
WOULD THE LEVEL OF TB UNITS   NEEDED TO REMAIN
AS SATISFIED AS AT THE INITIAL CONDITIONS
LIE BETWEEN 2.5 AND 1.5
 (Y/N)  ?y

SUPPOSE THAT YOU HAVE THE INITAL CONDITIONS:
TB UNITS  =5. AND TIME,YEARS=2.5

IMAGINE THAT YOU MUST ACCEPT
A LEVEL OF 4. IN TIME,YEARS
WOULD THE LEVEL OF TB UNITS
THAT YOU WOULD HAVE TO MOVE TO (IN ORDER TO BE AS
SATISFIED AS UNDER THE INITAL CONDITIONS) LIE
BETWEEN 8.5 AND 7.5
 (Y/N)  ?y
THERE ARE NO INDEPENDENCE PROBLEMS
WITH THE ATTRIBUTES TESTED SO FAR.
DO YOU WISH TO ASSUME MPI FOR THE
REMAINING ATTRIBUTES? (Y/N)
            ?n
EVEN IF YOU DO NOT WISH TO ASSUME
MPI AMOUNG THE ATTRIBUTES.
DO YOU WANT TO STOP MUI TESTIN

DO YOU WANT TO STOP MUI TESTING?  (Y/N).
            ?n
SINCE TB UNITS   IS PAIRWISE PREFEPENTIALLY
INDEPENDENT OF THE OTHER ATTRIBUTES, ATTRIBUTE
TB UNITS  WILL NOW BE TESTED FOR UTILITY INDEPENDENCE.

WITH THE OTHER ATTRIBUTES EXCEPT TB UNITS
SET AS THE FOLLOWING LEVELS

SPONSORS   = 2.5
TIME,YEARS = 1.25

NOW WHAT VALUE OF ATTPIBUTE TB UNITS  WITH CERTAINTY
WOULD YOU TPADE FOR A LOTTERY OF A 50-50 CHAN

WOULD YOU TRADE FOR A LOTTERY OF A 50-50 CHANCE OF
RECEIVING EITHER 10. UNITS OR 0. UNITS OF
ATTRIBUTE TB UNITS
     ?3
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NOW WHAT VALUE OF ATTRIBUTE TB UNITS  WITH CERTAINTY
WOULD YOU TRADE FOR A LOTTERY OF A 50-50 C

WOULD YOU TRADE FOR A LOTTERY OF A 50-50 CHANCE OF
RECEIVING EITHER 10. UNITS OR 3. UNITS OF
ATTRIBUTE TB UNITS
     ?6

NOW WHAT VALUE OF ATTRIBUTE TB UNITS  WITH CERTAINTY
WOULD YOU TRADE FOR A LOTTERY OF A 50-50 CHANCE OF
RECEIVING EITHER 3. UNITS OR 0. UNITS OF
ATTRIBUTE TB UNITS
      ?1.
AARON D.  , SUPPOSE NOW THAT THE FOLLOWING ATTRIBUTES
ARE SHIFTED TO THESE LEVELS:

SPONSORS  =7.5
TIME,YEARS=3.75
THAT IS AT THE 75 PERCENT LEVEL

NOW FOR THE LOTTERY OF A 50-50 CHANCE OF RECEIVING EITHER
10. UNITS OR 0. UNITS OF ATTRIBUTE TB UNITS
WOULD YOU TRADE FOR A VALUE OF ATTRIBUTE TB UNITS   WITH
CERTAINTY BETWEEN 3.5 UNITS AND 2.5
UNITS,  (Y/N)?y

NOW FOR THE LOTTERY OF A 50-50 CHANCE OF RECEIVING EITHER
10. UNITS OR 3. UNITS OF ATTRIBUTE TB UNITS
WOULD YOU TRADE FOR A VALUE OF ATTRIBUTE TB UNITS   WITH
CERTAINTY BETWEEN 6.5 UNITS AND 5.5
UNITS.  (Y/N)y

NOW FOR THE LOTTERY OF A 50-50 CHANCE OF RECEIVING EITHER
3. UNITS OR 0. UNITS OF ATTRIBUTE TB UNITS
WITH CERTAINTY BETWEEN 1.5 UNITS AND .5
UNITS.  (Y/N)y
ONLY "Y" OR "N" IS ALLOWED, AARON D.

NOW FOR THE LOTTERY OF A 50-50 CHANCE OF RECEIVING EITHER
3. UNITS OR 0. UNITS OF ATTRIBUTE TB UNITS
WITH CERTAINTY BETWEEN 1.5 UNITS AND .5
UNITS.  (Y/N)y
ONLY "Y" OR "N" IS ALLOWED, AARON D.

NOW FOR THE LOTTERY OF A 50-50 CHANCE OF RECEIVING EITHER
3. UNITS OR 0. UNITS OF ATTRIBUTE TB UNITS
WITH CERTAINTY BETWEEN 1.5 UNITS AND .5
UNITS.  (Y/N)y


  THE ATTRIBUTES ARE UTILITY INDEPENDENT



 THE UTILITY FUNCTIONS FOR EACH ATTRIBUTE
 WILL NOW BE DETERMINED
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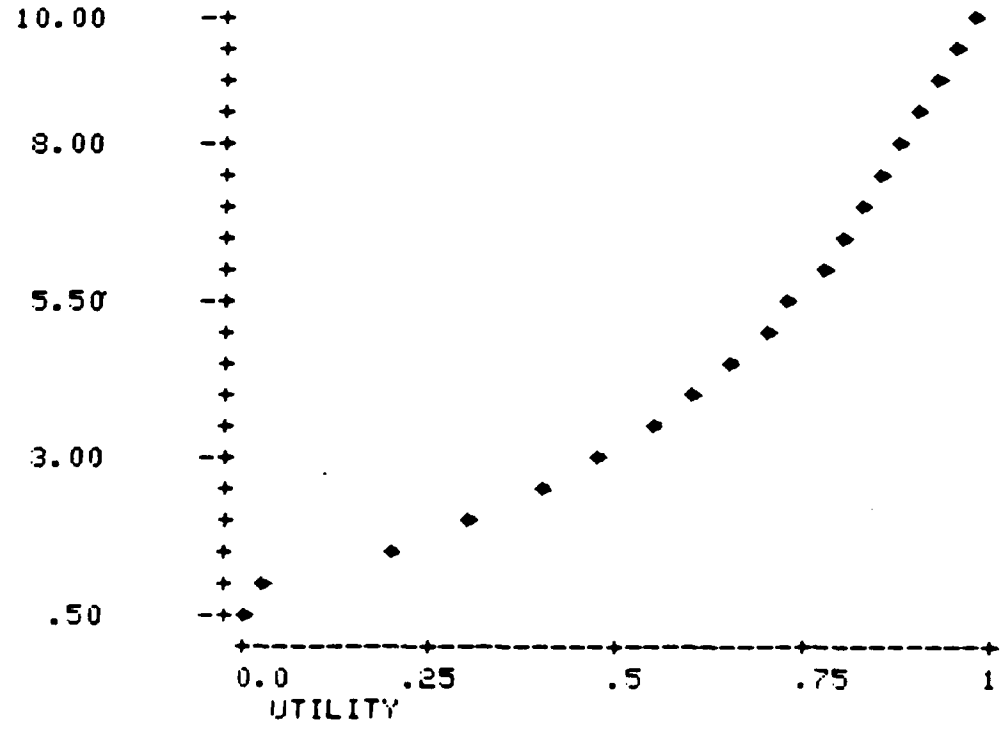
 THE UTILITY FUNCTIONS FOR EACH ATTRIBUTE
 WILL NOW BE DETERMINED


NOW WHAT  LEVEL OF ATTRIBUTE  TB UNITS
WITH CERTAINTY WOULD YOU TRADE FOR A LOTTERY
WITH A 50-50 CHANCE OF RECEIVING EITHER
10. UNITS OR 0. UNITS OF ATTRIBUTE  TB UNITS
     ?3

NOW WHAT  LEVEL OF ATTRIBUTE  TB UNITS
WITH CERTAINTY WOULD YOU TRADE FOR A LOTTERY
WITH A 50-50 CHANCE OF RECEIVING EITHER
3. UNITS OR 0. UNITS OF ATTRIBUTE  TB UNITS
     ?1.5

NOW WHAT  LEVEL OF ATTRIBUTE  TB UNITS
WITH CERTAINTY WOULD YOU TRADE FOR A LOTTERY
WITH A 50-50 CHANCE OF RECEIVING EITHER
3. UNITS OR 10. UNITS OF ATTRIBUTE  TB UNITS
     ?6

THE ABOVE YIELDS A UTILITY FUNCTION FOR  TB UNITS
WITH PARAMETERS:
B0=.0360853789916     B1=.4143262372915
SUM OF SQUARED ERROR=.00439475958282
(LOGARITHMIC FORM)
UTILITY=B0+B1*LN(ATTRIBUTE LEVEL)
```

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UTILITY FUNCTION FOR  TB UNITS

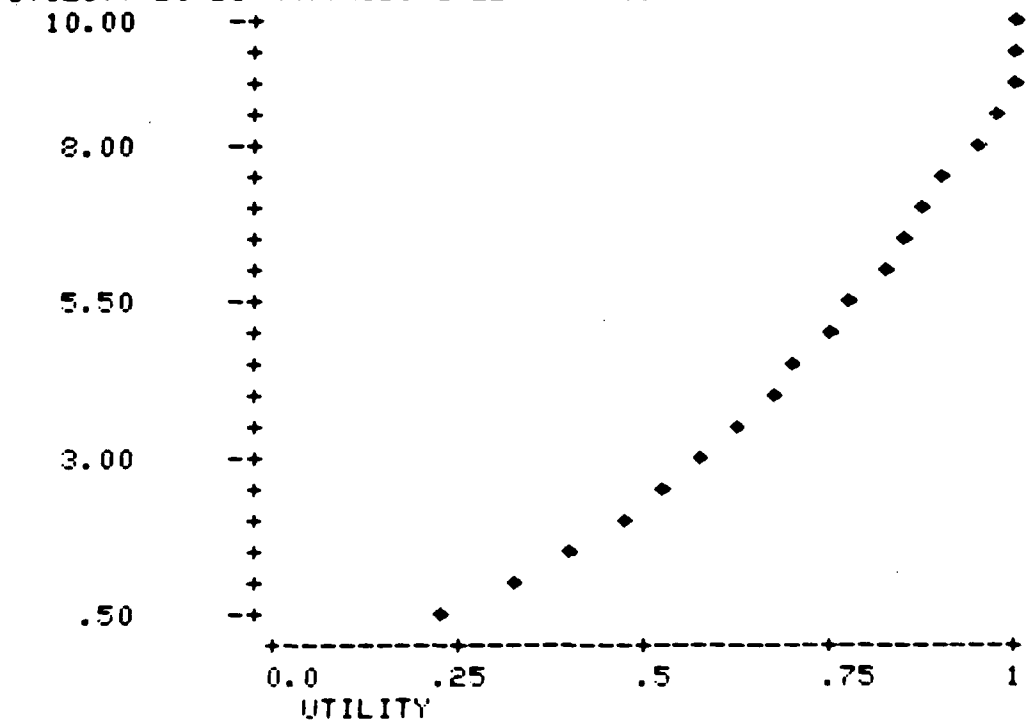
DOES THE ABOVE REPRESENTATION APPEAR REASONABLE? (Y/N)
     ?Y
```

```
NOW WHAT  LEVEL OF ATTRIBUTE SPONSORS
WITH CERTAINTY WOULD YOU TRADE FOR A LOTTERY
WITH A 50-50 CHANCE OF RECEIVING EITHER
10. UNITS OR 0. UNITS OF ATTRIBUTE SPONSORS
     ?2

NOW WHAT  LEVEL OF ATTRIBUTE SPONSORS
WITH CERTAINTY WOULD YOU TRADE FOR A LOTTERY
WITH A 50-50 CHANCE OF RECEIVING EITHER
2. UNITS OR 0. UNITS OF ATTRIBUTE SPONSORS
     ?1

NOW WHAT  LEVEL OF ATTRIBUTE SPONSORS
WITH CERTAINTY WOULD YOU TRADE FOR A LOTTERY
WITH A 50-50 CHANCE OF RECEIVING EITHER
2. UNITS OR 10. UNITS OF ATTRIBUTE SPONSORS
     ?3

THE ABOVE YIELDS A UTILITY FUNCTION FOR SPONSORS
WITH PARAMETERS:
B0=.01501703492854     B1=.3317918697555
SUM OF SQUARED ERROR=.03966886467344
(SQUARE-ROOT FORM)
UTILITY=B0+B1*(ATTRIBUTE LEVEL)**0.5
```




```
UTILITY FUNCTION FOR SPONSORS

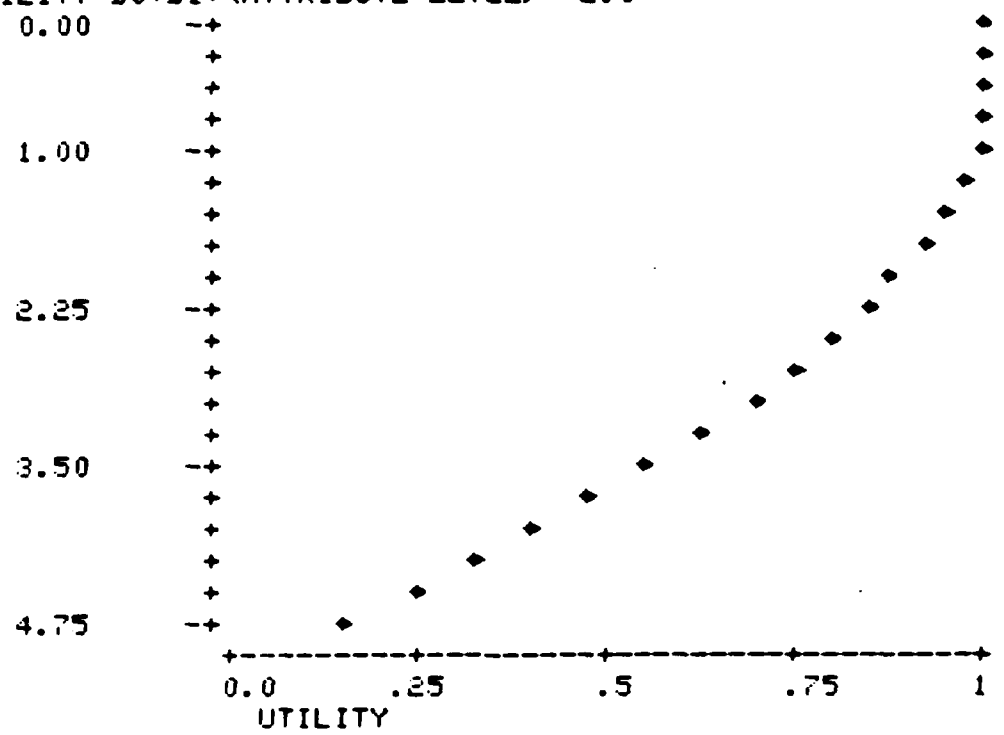
DOES THE ABOVE REPRESENTATION APPEAR REASONABLE? (Y/N)
     ?y
```

```
NOW WHAT  LEVEL OF ATTRIBUTE TIME,YEARS
WITH CERTAINTY WOULD YOU TRADE FOR A LOTTERY
WITH A 50-50 CHANCE OF RECEIVING EITHER
0. UNITS OR 5. UNITS OF ATTRIBUTE TIME,YEARS
     ?4

NOW WHAT  LEVEL OF ATTRIBUTE TIME,YEARS
WITH CERTAINTY WOULD YOU TRADE FOR A LOTTERY
WITH A 50-50 CHANCE OF RECEIVING EITHER
4. UNITS OR 5. UNITS OF ATTRIBUTE TIME,YEARS
     ?4.5

NOW WHAT  LEVEL OF ATTRIBUTE TIME,YEARS
WITH CERTAINTY WOULD YOU TRADE FOR A LOTTERY
WITH A 50-50 CHANCE OF RECEIVING EITHER
4. UNITS OR 0. UNITS OF ATTRIBUTE TIME,YEARS
     ?3

THE ABOVE YIELDS A UTILITY FUNCTION FOR TIME,YEARS
WITH PARAMETERS:
B0=1.058734255292     B1=-.0397675626542
SUM OF SQUARED ERROR=.01605919685755
(SQUARED FORM)
UTILITY=B0+B1*(ATTRIBUTE LEVEL)**2.0
```




```
UTILITY FUNCTION FOR TIME,YEARS

DOES THE ABOVE REPRESENTATION APPEAR REASONABLE? (Y/N)
     ?y
```

```
YOU MAY NOW ENTER WEIGHTS, VALUES, OR (RE)CALCULATE
THE TREE.  CHOOSE YOUR OPTION:
  W(EIGHT      V(ALUES      C(ALCULATE      E(XIT

     ?v

VALUES     :  A(LL      S(ELECT
     ?a

WE ARE AT THE DATA NODE:                              DATA FOR
 TO START R AND D PROJECTS WITH AN                    PROJECT S
 ESTABLISHED TECHNOLOGY BASE WITH WHICH
 TO MEET IDENTIFIED NEEDS
  (TECHNOLOGY BASE UNITS - TB UNITS)
WHICH HAS THE ASSOCIATED ATTRIBUTE  TB UNITS

THE CURRENT SPIKE PROBABILITY (SEE
USER'S MANUAL) FOR  TB UNITS
AT A LEVEL OF 1. IS 0.

WHAT IS THE NEW SPIKE PROBABILITY
     ?0

THE CURRENT SPIKE PROBABILITY (SEE
USER'S MANUAL) FOR  TB UNITS
AT A LEVEL OF 2. IS 0.

WHAT IS THE NEW SPIKE PROBABILITY
     ?0

THE CURRENT SPIKE PROBABILITY (SEE
USER'S MANUAL) FOR  TB UNITS
AT A LEVEL OF 3. IS 0.

WHAT IS THE NEW SPIKE PROBABILITY
     ?.25

THE CURRENT SPIKE PROBABILITY (SEE
USER'S MANUAL) FOR  TB UNITS
AT A LEVEL OF 4. IS 0.

WHAT IS THE NEW SPIKE PROBABILITY
     ?.5

THE CURRENT SPIKE PROBABILITY (SEE
USER'S MANUAL) FOR  TB UNITS
AT A LEVEL OF 5. IS 0.

WHAT IS THE NEW SPIKE PROBABILITY
     ?.25
```

```
THE CURRENT SPIKE PROBABILITY (SEE
USER'S MANUAL) FOR  TB UNITS
AT A LEVEL OF 6. IS 0.

WHAT IS THE NEW SPIKE PROBABILITY
     ?0

THE CURRENT SPIKE PROBABILITY (SEE
USER'S MANUAL) FOR  TB UNITS
AT A LEVEL OF 7. IS 0.

WHAT IS THE NEW SPIKE PROBABILITY
     ?0

THE CURRENT SPIKE PROBABILITY (SEE
USER'S MANUAL) FOR  TB UNITS
AT A LEVEL OF 8. IS 0.

WHAT IS THE NEW SPIKE PROBABILITY
     ?0

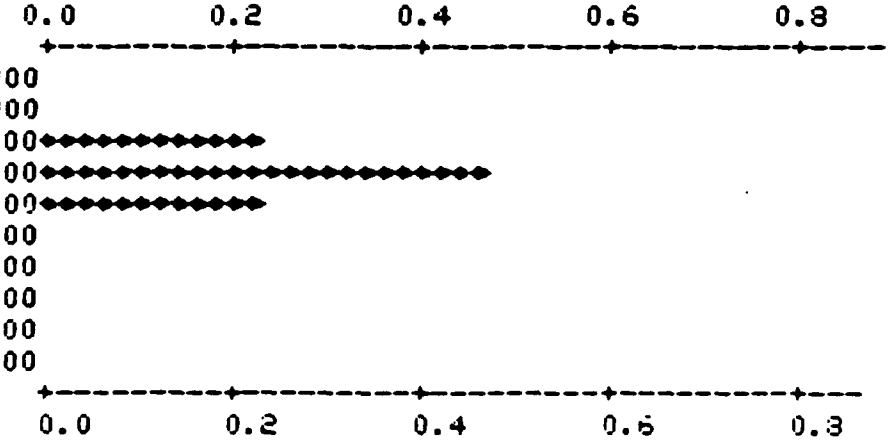
THE CURRENT SPIKE PROBABILITY (SEE
USER'S MANUAL) FOR  TB UNITS
AT A LEVEL OF 9. IS 0.

WHAT IS THE NEW SPIKE PROBABILITY
     ?0

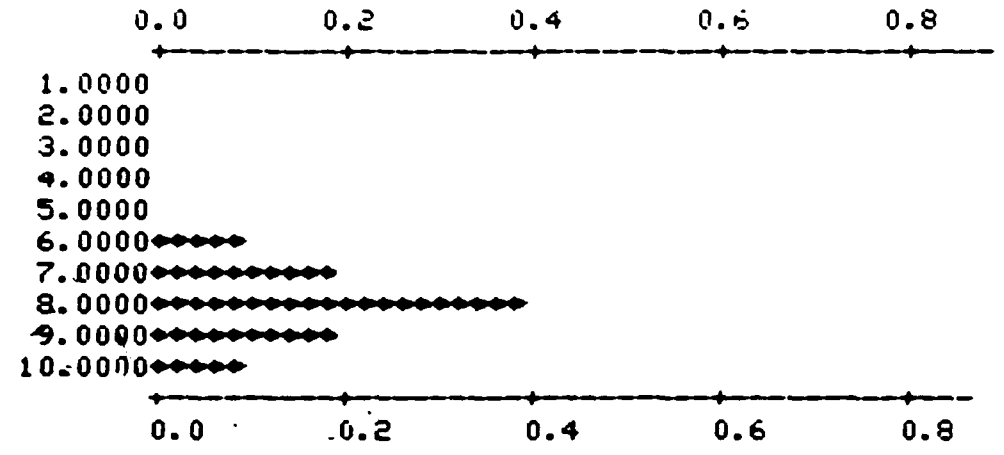
THE CURRENT SPIKE PROBABILITY (SEE
USER'S MANUAL) FOR  TB UNITS
AT A LEVEL OF 10. IS 0.

WHAT IS THE NEW SPIKE PROBABILITY
     ?0

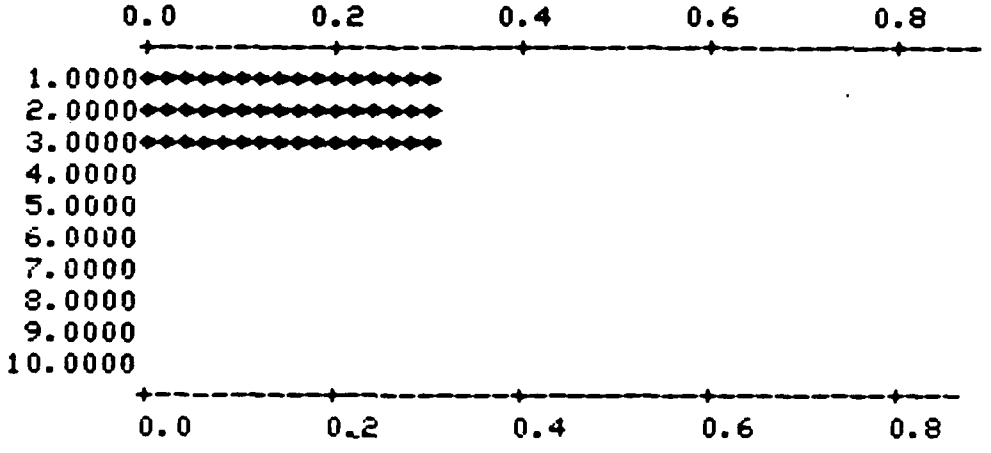
THE SPIKE PROBABILITIES RESULT IN THE
FOLLOWING PLOT:
```



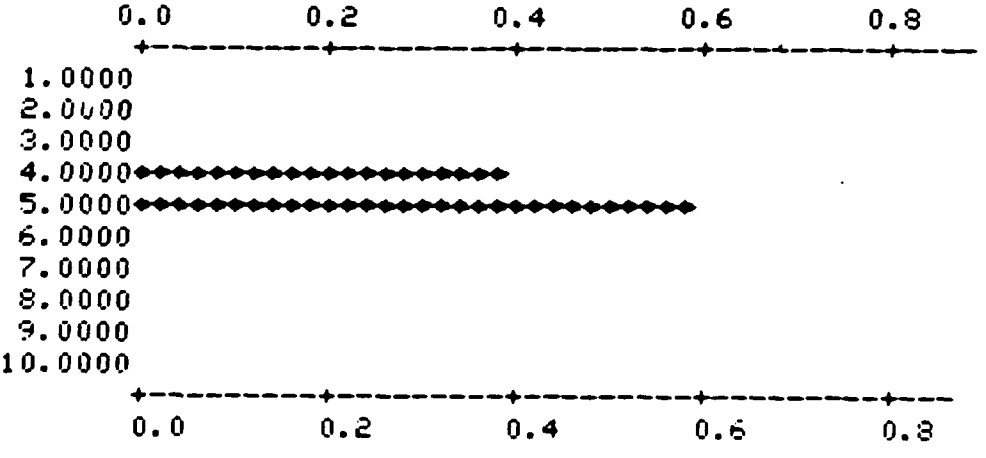
SPIKE PROBABILITIES FOR ATTRIBUTE TB UNITS PROJECT S
(Y-AXIS IS ATTRIBUTE LEVEL)



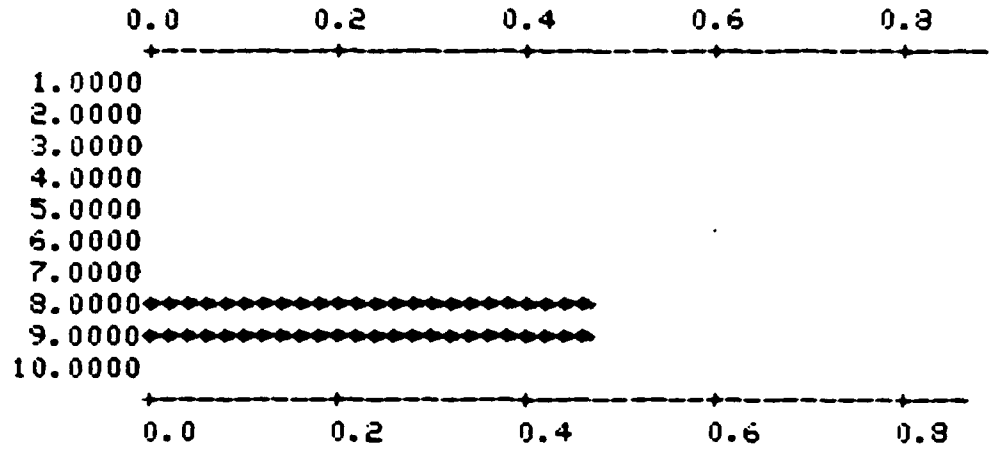
SPIKE PROBABILITIES FOR ATTRIBUTE TB UNITS PROJECT T
(Y-AXIS IS ATTRIBUTE LEVEL)



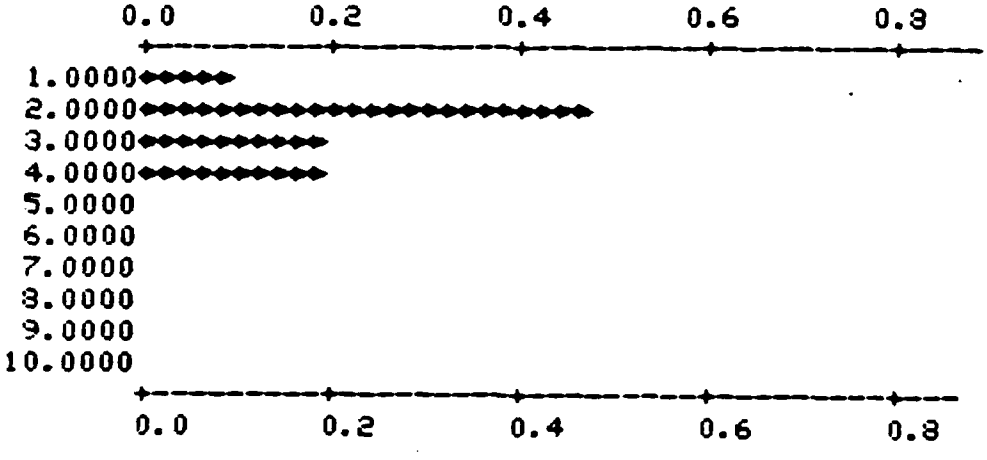
SPIKE PROBABILITIES FOR ATTRIBUTE TB UNITS PROJECT X
(Y-AXIS IS ATTRIBUTE LEVEL)



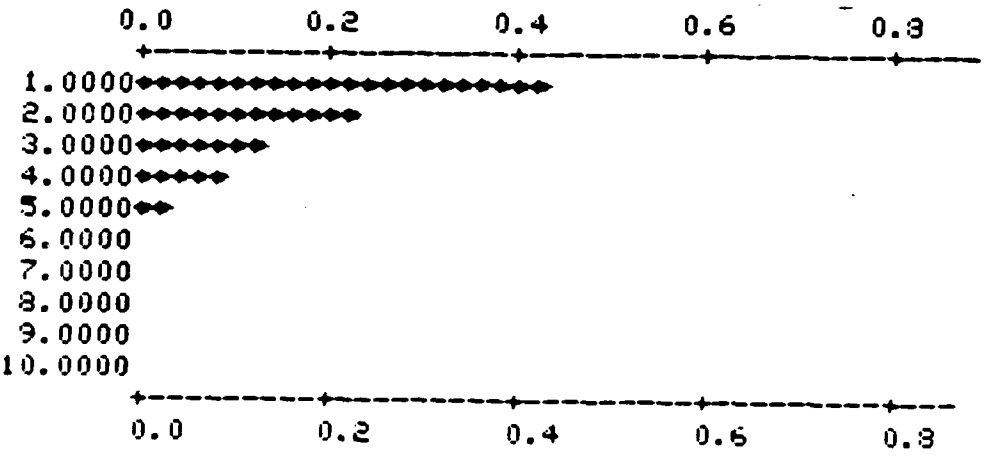
SPIKE PROBABILITIES FOR ATTRIBUTE TB UNITS PROJECT Y
(Y-AXIS IS ATTRIBUTE LEVEL)



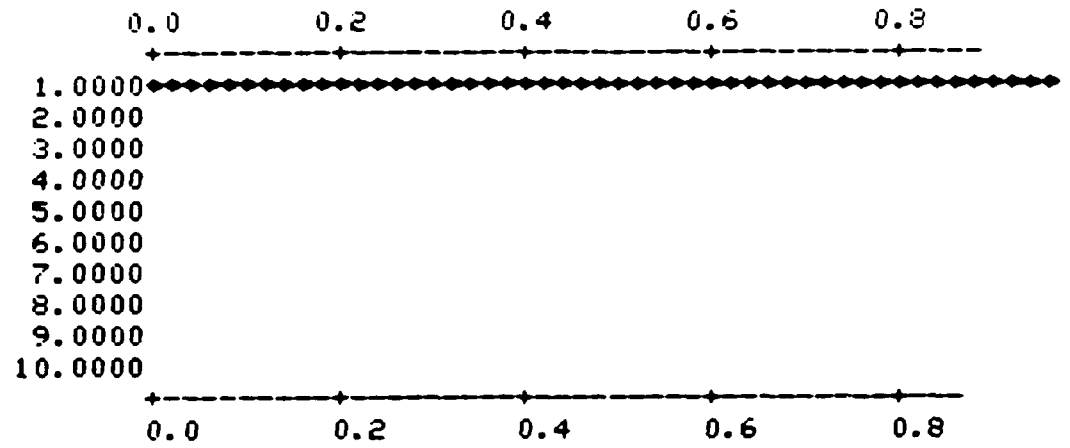
SPIKE PROBABILITIES FOR ATTRIBUTE TB UNITS PROJECT Z
(Y-AXIS IS ATTRIBUTE LEVEL)



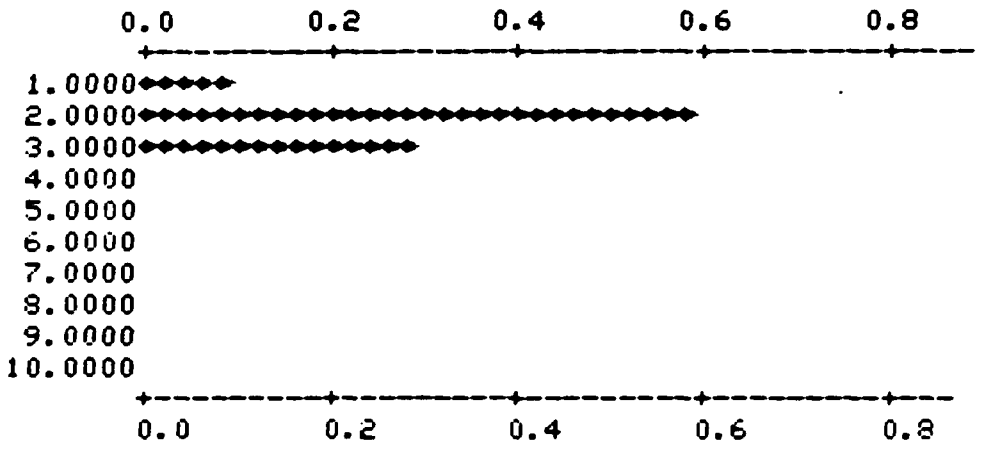
SPIKE PROBABILITIES FOR ATTRIBUTE SPONSORS PROJECT S
(Y-AXIS IS ATTRIBUTE LEVEL)



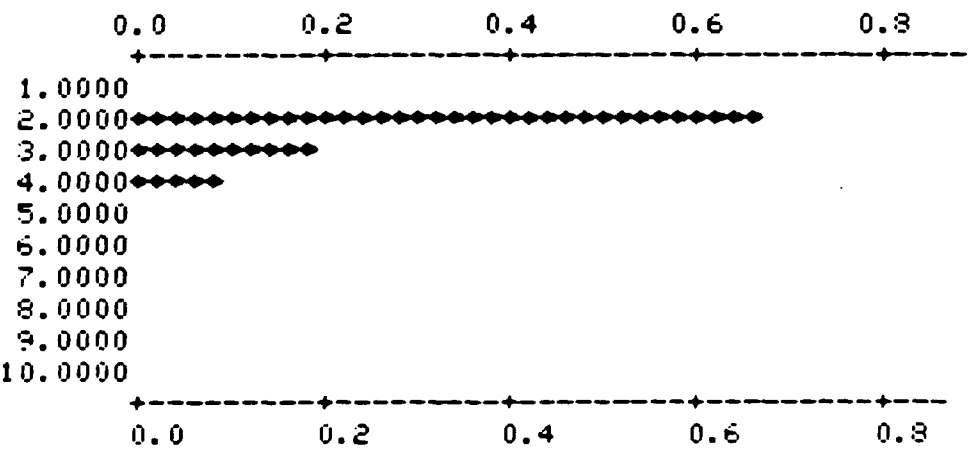
SPIKE PROBABILITIES FOR ATTRIBUTE SPONSORS PROJECT T
(Y-AXIS IS ATTRIBUTE LEVEL)



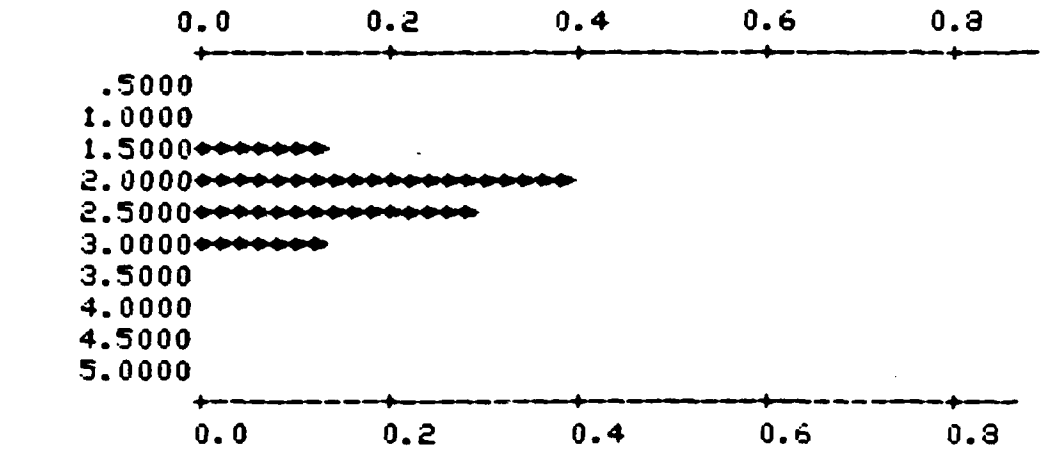
SPIKE PROBABILITIES FOR ATTRIBUTE SPONSORS PROJECT X
(Y-AXIS IS ATTRIBUTE LEVEL)



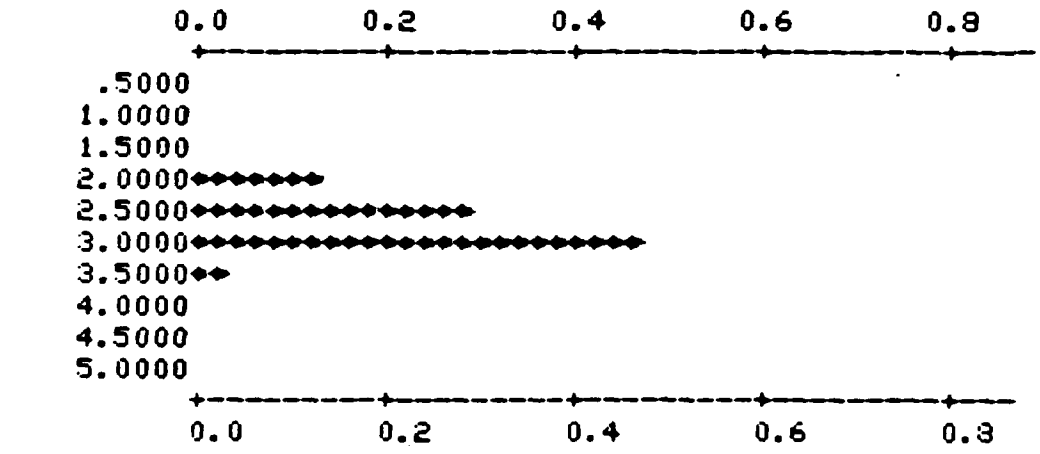
SPIKE PROBABILITIES FOR ATTRIBUTE SPONSORS PROJECT Y
(Y-AXIS IS ATTRIBUTE LEVEL)



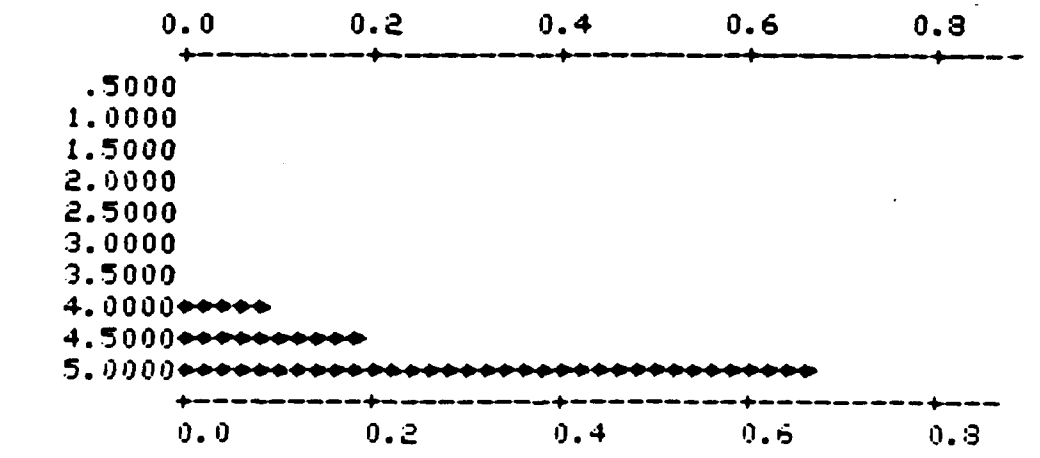
SPIKE PROBABILITIES FOR ATTRIBUTE SPONSORS PROJECT Z
(Y-AXIS IS ATTRIBUTE LEVEL)



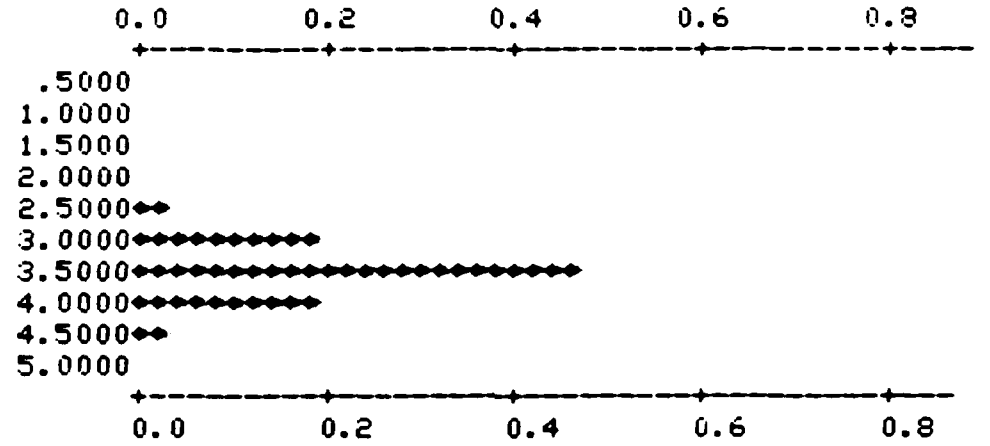
SPIKE PROBABILITIES FOR ATTRIBUTE TIME,YEARS PROJECT S
(Y-AXIS IS ATTRIBUTE LEVEL)



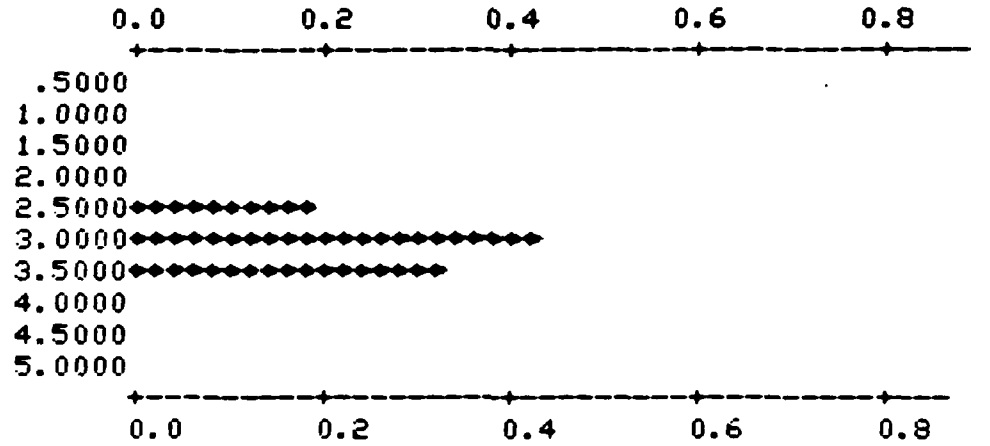
SPIKE PROBABILITIES FOR ATTRIBUTE TIME,YEARS PROJECT T
(Y-AXIS IS ATTRIBUTE LEVEL)



SPIKE PROBABILITIES FOR ATTRIBUTE TIME,YEARS PROJECT X
(Y-AXIS IS ATTRIBUTE LEVEL)



SPIKE PROBABILITIES FOR ATTRIBUTE TIME,YEARS PROJECT Y
(Y-AXIS IS ATTRIBUTE LEVEL)



SPIKE PROBABILITIES FOR ATTRIBUTE TIME,YEARS PROJECT Z
(Y-AXIS IS ATTRIBUTE LEVEL)

PROJECT DATA ENTERED

YOU MAY NOW ENTER WEIGHTS, VALUES, OR (RE)CALCULATE
THE TREE. CHOOSE YOUR OPTION:
W(EIGHT V(ALUES C(ALCULATE E(XIT)

?w

```
WE ARE WEIGHTING THE NODE SET:
 TO EXPAND TECHNOLOGY BASE, BUT NOT AT

 EXPENSE OF FOCUSED R AND D EFFORTS

THE ABOVE OBJECTIVE IS FACTOR 1
 TO GAIN SPONSORSHIP FOR FUNDING THE

 ADVANCED DEVELOPMENT OF R AND D PROJECT
S
THE ABOVE OBJECTIVE IS FACTOR 2
 TO REALIZE SIGNIFICANT

 RESULTS IN MINIMUM TIME

THE ABOVE OBJECTIVE IS FACTOR 3

DO YOU WISH TO ENTER THE RELATIVE WEIGHTS DIRECTLY,
(Y/N)  ?y
ENTER THE (UNNORMALIZED) WEIGHTS.
WHAT IS THE WEIGHT FOR FACTOR 1
     ?2
WHAT IS THE WEIGHT FOR FACTOR 2
     ?5
WHAT IS THE WEIGHT FOR FACTOR 3
     ?3
NORMALIZED:20 50 30

ARE YOU HAPPY WITH THESE RELATIVE WEIGHTS? (Y/N)
     ?y
ENTER COMMENTS ON THESE WEIGHTS
?ok



YOU MAY NOW ENTER WEIGHTS, VALUES, OR (RE)CALCULATE
THE TREE.  CHOOSE YOUR OPTION:
  W(EIGHT     V(ALUES     C(ALCULATE     E(XIT

     ?C
INTERIOR TREE VALUES ARE BEING CALCULATED...
```

```
HOW MUCH DO YOU WANT TO REVIEW...
     A(LL      S(ELECT
     ?a
IF ANY MODIFICATIONS HAVE BEEN MADE TO THE TREE
SINCE IT HAS BEEN CALCULATED ,NUMERICAL VALUES
WILL BE INCORRECT.
(PRESS ANY LETTER TO CONTINUE)
     ?r



                        REVIEW
 RESEARCH AND DEVELOPMENT
 FUNDS ALLOCATION -
 PROJECT SELECTION

NODE REFERENCE NUMBER(AND OBJECTIVE):
 1
 TO PROVIDE FOR SUCCESSFUL

 R AND D EFFORTS

RELATIVE WEIGHT: 1.
CUMULATIVE WEIGHT: 1.

SYSTEM VALUES:
PROJECT S       PROJECT T       PROJECT X       PROJECT Y
    64.30           64.68           27.15           53.74
PROJECT Z
    65.01

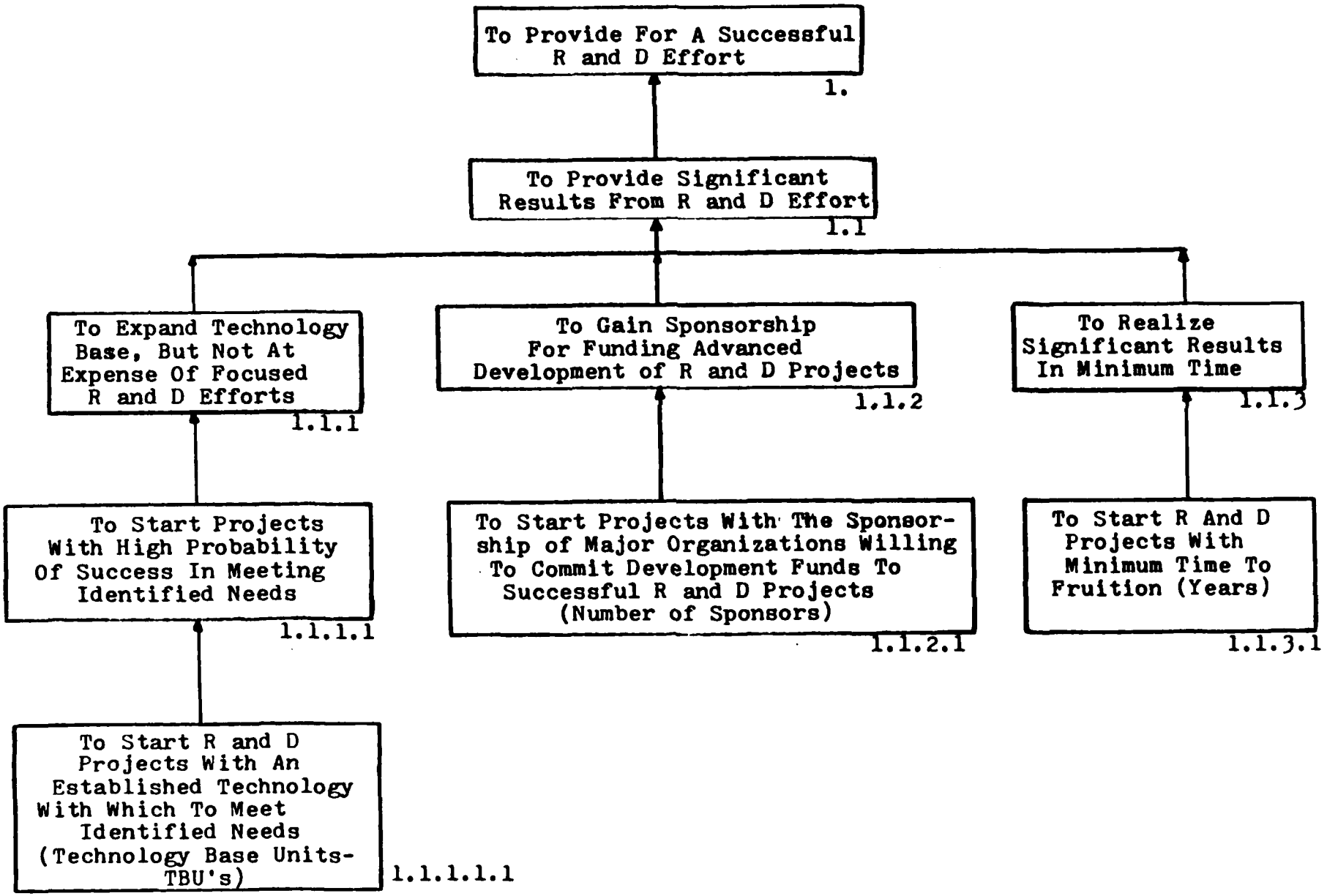
    OK
(PRESS ANY LETTER TO CONTINUE (EXCEPT "E"))
(PRESS "E" TO EXIT)
     ?r
```

Appendix C
Technology Base Units

The following scale was used to note projects on the attribute reflecting technical foundation of a research area.

Characteristic	Technology Base (TB) Scale 0-10
Research Base Fully Developed Adequate Data To Go Into Production	9
Research Base Developing With Foundation For Further Development, Growing Data Base For Specific Technology	7
Research Base Partially Developed, Some Data Available On Specific Technology	5
Research Base Undeveloped, Data Available But Only From Related Areas	3
Research Base Undeveloped, Technology Area New, No Data	1

Appendix D - Objectives Hierarchy - R and D Funds Allocation



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8a. NAME OF FUNDING/SPONSORING ORGANIZATION; 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
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FIELD	GROUP	SUB. GR.	Decision Making, Statistical Analysis, Decision Theory, Computer Application, Project Assessment.

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This research is an on-going effort to produce an interactive, computer-based aid suitable for use in decision situations and long-term planning. The current research involves the development of extensions to the applicability of a decision aid embodied in the computer program MADAM: Multi-Attribute Decision Analysis Model. The theoretical underpinnings of MADAM involve portions of multi-attribute utility theory. This interactive program is designed to aid the decision-maker in all phases of decision analysis from problem formulation to sensitivity analysis. The program is a tool designed to be used by a decision-maker in order to facilitate making rational and consistent trade-offs and sub-decisions throughout the entire decision-making process. The stages of the decision analysis covered by the program include formation of an objectives hierarchy, elicitation of an appropriate set of attributes, examining the relationship between the attributes, establishing criterion weights, evaluating candidate solutions, and performing several types of sensitivity analysis.

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Item 19. (Cont'd)

The significant changes in the model involve the stages of examining the relationship between the attributes and of incorporating probabilistic data and utility concepts. In the previous version of MADAM, the program guides the decision-maker in determining whether or not the condition of mutual preferential independence is met. This determination is important because the previous version of the program is designed to handle the case of deterministics attributes (measurable value analysis) where an additive value function is the appropriate overall value function. The extension allow MADAM to be utilized for the case of probabilistic attributes (utility analysis). The extended program aids the decision-maker in conducting lottery trade-offs so that independence conditions necessary to use an additive utility function can be ascertained. The utility analysis parallels the former value analysis in structure. MADAM maintains all previous capabilities for sensitivity analysis as well as the new utility analysis capabilities.

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